

Phase 2 Focused Remedial Investigation Technical Memorandum

for the
**Diamond Head Oil Superfund
Site
Kearny, New Jersey**

Prepared by:



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Introduction

1.1 Introduction

This draft Technical Memorandum (TM) is submitted to the United States Environmental Protection Agency (USEPA), Region II, under Task Order DH02 Under contract No. DACA87-02-D-0006 with the U.S. Army Corps of Engineers. Under this Task Order, CH2M HILL performed a Focused Phase 2 Remedial Investigation (RI) of the Diamond Head Oil Refinery site in Kearny, Hudson County, New Jersey.

The general objectives of this Focused Phase 2 RI were to investigate the following:

- Light nonaqueous-phase liquid (LNAPL) source area
- Former landfill

The investigation activities involved collecting focused information supporting evaluation of remedial alternatives for implementation of an interim remedial measure (IRM) for the LNAPL found at the site.

The Phase 2 RI was conducted in accordance with the *Focused Remedial Investigation/ Feasibility Study (RI/FS) Work Plan* (CH2M HILL, June 2007b) developed at the start of this phase of activities. Phase 2 objectives defined the activities that would be completed in accordance with the following project planning documents:

- Quality Assurance Project Plan (CH2M HILL, 2007d)
- Sampling and Analysis Plan (CH2M HILL, 2007e)
- Contractor Quality Control Plan (CH2M HILL, 2007a)
- Health and Safety Plan (CH2M HILL, 2007c)
- Site Management Plan (CH2M HILL, 2007f)

This draft TM summarizes the data collected during this phase of investigation activities. It presents an interpretation of these data, and documents the nature and extent of the identified LNAPL contamination and landfill characteristics. Based on the data, this TM then makes preliminary recommendations on next steps in addressing the LNAPL contamination.

This rest of Section 1 comprises the following:

- Site background
- Objectives of the Phase 2 RI/FS
- Purpose and organization of this TM

1.2 Site Background

1.2.1 Site Description

The Diamond Head Oil Refinery site is currently inactive and consists of approximately 15 acres of undeveloped land located near the Hackensack Meadowlands (Figure 1-1). Figure 1-2 shows the locations of the Focused Phase 2 investigation activities over an aerial

photograph of the area. Figure 1-3 is a site plan showing the major site features, including the former landfill, foundations of former tanks and buildings, access road, and the outline of the current onsite wetlands delineated during the Phase 1 RI at the site. Figure 1-3 also shows the quadrants for which figures showing the details of the investigation activities were prepared.

The property is currently owned by the Hudson Meadows Development Corporation. For purposes of this TM, "site" refers to any place where contamination from the former Diamond Head Oil Refinery has migrated. Property refers to the physical property occupied by the former Diamond Head Oil Refinery.

The site is bordered on the north by Harrison Avenue, on the east by the entrance ramp of Interstate 280 (I-280), on the south by a drainage channel bordering I-280, and on the west by a salvage operation. The area surrounding the site is industrial; there are no residential areas near the site. Land use within 1,000 feet of the site consists of light industrial to the northwest and west, wetlands (meadowlands) to the east and south, and unused vegetated land to the north.

The topography of the site is flat over the east section—where the former reprocessing area/lagoon were located and over the west section between the landfill and the Public Service Electric and Gas (PSE&G) right-of-way. Based on site reconnaissance, the former oil lagoon and the wetlands areas currently found within the footprint of the former lagoon appear to be in a topographically low area of the site. A change in elevation of approximately 10 to 15 feet above the east and west sections of the site demarcates the boundary of the former landfill. Because of the debris present throughout the site and because the elevation of the landfill varies, its limit is not always clearly defined. Approximately 70 percent of the site is covered by Phragmites up to 15 feet tall, which make access difficult.

The major surface water bodies within 0.5 mile of the Diamond Head Property that are topographically and hydraulically downgradient of the site are Frank's Creek and the Passaic River. Drainage on the site flows to the east and south and collects in a drainage swale that also collects water from the I-280 entrance ramp near the southeastern boundary of the site. The water then flows westward and joins Frank's Creek, which has been modified from its original course by development activities. Frank's Creek flows southward and eventually discharges to the Passaic River approximately 3,600 feet west of the Interstate 95 (I-95) bridge.

A detailed description of the site history is provided in Section 1 of the Phase 1 Remedial Investigation Technical Memorandum (CH2M HILL, 2005).

1.2.2 Historical Potential Sources of Contamination

The following three areas of the site have been identified as potential sources that may be continuing to release contamination to the environment:

- Landfill—with an approximate area of 7 acres
- Oil-reprocessing section of the site—with two buildings, multiple aboveground storage tanks (ASTs), drum storage areas, and possibly underground pits
- Oil lagoon—with an approximate area of 5 acres located over the south section of the site and extending outside the site boundaries to the east and south

Only the foundations of one of the buildings and two of the ASTs are visible in the oil-processing section of the site. While the general location of the landfill can be identified, its exact limits are often unclear because the elevation changes gradually and debris is present over the entire site and cannot serve as a demarcating factor. Figure 1-3 shows the general outline of the landfill and the foundations of the former building and ASTs. There are no physical demarcations at the site that can be used to establish the boundary of the former lagoon. Historic information suggests that the lagoon occupied the southeast section of the site and extended eastward from there beyond the current boundary of the site.

1.2.3 Chronology of Previous Investigations

Prior to the initiation by USEPA Region II of the Phase 1 RI at the site, four limited investigations were performed to gain an understanding of site conditions and contamination. These included:

- A sampling event conducted by the New Jersey Department of Environmental Protection (NJDEP) in 1985
- An environmental site characterization conducted by Killam Associates in 1990
- Two site inspections conducted by the USEPA Region 2 Field Investigation Team—one in 1991 and one in 1999

During these investigations, samples of groundwater, surface water, sediment, surface and subsurface soil, liquid waste, and solid waste were collected. Detailed descriptions of the scope of these investigations and their results can be found in Section 1 of the Phase 1 Remedial Investigation Technical Memorandum (CH2M HILL, 2005). At the start of the Phase 1 RI, the data collected during these investigations was reviewed to determine its quality, and based on that, whether it could be used to supplement the results from the Phase 1 RI. This review indicated that the data collected during USEPA's site inspections could be used to supplement the results of the Phase 1 RI. Because the 1991 data had been collected almost 15 years before the start of the Phase 1 RI, however, it was decided that these data should not be used. The 1991 data were used to supplement the Phase 1 RI data in assessing site contamination conditions.

In 2003, USEPA Region II initiated the RI/FS of the Diamond Head Oil Refinery site.

The broad objectives of the RI/FS were defined to obtain data on the nature and extent of soil, groundwater, surface water, and sediment contamination associated with the site, assess the associated human health and ecological risks, and evaluate appropriate remedial alternatives.

To meet these overall objectives, a phased approach was selected and the Phase 1 remedial investigation was performed to:

- Obtain information on contamination in areas and media of the site where there was no information. Investigated media included surface and subsurface soil, groundwater, surface water, and sediments.
- Investigate the extent of the LNAPL that was observed in monitoring well MW-3 in the former lagoon area.
- Investigate groundwater conditions at the upgradient and downgradient boundaries of the landfill and at the upgradient and downgradient boundaries of the site.

As previously noted, the results of the Phase 1 RI were supplemented with the results from USEPA's 1999 inspection and together these results, were used to determine the extent of the existing site contamination and the need for and scope for the Phase 2 investigation.

The summary of previous investigations presented in the next section is based on the results presented in the Phase 1 Technical Memorandum (CH2M HILL, 2005). Some of the applicable criteria have changed since the Phase 1 TM was prepared. The summary presented in the next section reflects comparisons of Phase 1 contaminant concentrations to the criteria in effect at the time of preparation of the Phase 1 TM. The scope of this Phase 2 TM is to evaluate the LNAPL and landfill at the site and not to evaluate overall site contamination, as was the objective of the Phase 1 TM. Comparing Phase 1 results to revised criteria is, therefore, not included in this Phase 2 TM, but would be addressed as part of future supplemental investigations into overall site contamination.

1.2.4 Summary of Results from Previous Site Investigations

The Phase 1 RI indicated the widespread presence of oil—there was evidence of oil in all of the Phase 1 borings and in half of the 1999 borings. In addition, an LNAPL was found in the southeast corner of the site in the area of the former lagoon.

Based on this widespread oil contamination at the site, it was determined that before addressing residual chemical contamination the LNAPL—which likely is continuing to release contamination to the environment—should be investigated and addressed.

Other specific conclusions from the Phase 1 activities are summarized below.

Site Geology

The stratigraphy at the Diamond Head site consists of a relatively uniform vertical sequence of unconsolidated materials as follows:

- Anthropogenic fill materials of varying thickness across the site and consisting of typical demolition-type debris including wood, brick, metal pieces, glass, plastic pieces, and concrete mixed in a matrix of poorly sorted fine to coarse sand and gravel or silt, sand, and gravel.
- Sand unit about 5 feet thick on the western side of the site and pinching out until it is not present on the eastern side of the site.
- A silty clay unit up to 8 feet thick in sections of the site.
- A distinctive peat layer of varying thickness but considered continuous across the site.
- Silt and sand unit approximately 17 feet thick beneath the peat.
- Laminated silt and clay unit, the full thickness of which was not observed during the Phase 1 RI.
- Bedrock was not encountered in the 50-foot borings installed during the Phase 1 RI.

Site Hydrogeology

Two factors have a significant influence on the water table at the Diamond Head site. The first is the presence of delineated wetlands in the southeast corner and along the southern boundary of the site, and the second is the presence of an LNAPL plume in the southeast

corner of the site in the area of the former lagoon. Although lighter than water, the density of the LNAPL has the effect of depressing the water table and influencing groundwater flow.

Not considering wetland areas with standing water, groundwater is first encountered at the site under unconfined conditions at a depth of about 1.5 feet below ground surfaced (bgs). An area of high groundwater elevation occurs in the southeast corner of the site from where the groundwater flows radially toward the northeast, northwest, and southwest.

In the water-bearing unit below the peat, groundwater flows from northeast to southwest, consistent with regional trends in groundwater flow.

A vertical hydraulic head gradient exists between the groundwater unit above the peat and the groundwater unit below the peat. This vertical gradient is one to two orders of magnitude greater than the horizontal component and downward groundwater migration is, therefore, expected to be the dominant component of groundwater flow at the site.

The piezometric surfaces observed for the water bearing zones above and below the peat appear to be influenced by both barometric and tidal influences. The water-bearing zone above the peat appears most affected by regional barometric fluctuations, and the water-bearing unit below the peat appears most affected by tidal fluctuations related to the nearby Passaic River.

Nature and Extent of Contamination in Surface Soils

The surface soil samples collected at all Phase 1 sampling locations contained organic constituents (volatile organic compounds [VOCs] and semivolatile organic compounds [SVOCs]). Metals were also detected at all but one of the sampled locations. Most locations (49 of the 53 sampled) showed both organic and inorganic (metals) compounds at concentrations above the applicable criteria. The polycyclic aromatic hydrocarbons (PAHs) and metals (lead, in particular) were the predominant compounds exceeding criteria in surface soil. Total polychlorinated biphenyls (PCBs) also exceeded criteria at 23 of the 53 locations sampled.

Nature and Extent of Contamination in Subsurface Soils

The subsurface soil samples collected at all Phase 1 sampling locations contained organic compounds (VOCs and/or SVOCs). Metals were also detected at all of the locations sampled for metals.

The subsurface soil samples collected above the peat at nearly half the locations contained compounds (VOCs and/or SVOCs) at concentrations above the New Jersey discharge to groundwater criteria, with the VOCs predominantly exceeding criteria. When comparing VOC and SVOC concentrations in subsurface soils above the peat to the New Jersey direct contact criteria, however, predominantly the SVOCs and the metals exceeded the criteria for direct contact.

The total VOC and SVOC isoconcentration contour maps above the peat suggest the highest total VOC and SVOC concentrations occur—east of the landfill—within the former lagoon and former refinery area. Elevated concentrations of individual VOC compounds above discharge to groundwater criteria potentially continues offsite to the I-280 cloverleaf, although not along Harrison Turnpike and not in the borings above the peat west of the landfill. The presence of individual SVOC compounds above these criteria does not extend to the cloverleaf or along the boundary of the site. When subsurface soils are compared to the New Jersey direct contact criteria, however, all three locations within the I-280 cloverleaf

exceed these criteria for SVOCs and metals, and one location exceeds criteria for pesticides.

Analytical results suggest that VOC and SVOC contamination found above the discharge to groundwater criteria in soils above the peat decreases below the peat, and all concentrations below the peat were below the criteria.

Pesticides and metals did not exceed their discharge to groundwater criteria above and below the peat; however, pesticides exceed the New Jersey direct contact criteria above the peat and metals (antimony, arsenic, barium, beryllium, cadmium, copper, lead, mercury, and nickel) exceed the New Jersey direct contact criteria above and below the peat.

Total PCBs exceed the New Jersey direct contact criteria at nearly half the sampled locations. They were not found at concentrations above the discharge to groundwater criteria.

Nature and Extent of LNAPL Contamination

The LNAPL present in the former lagoon area was estimated to cover an area of approximately 80,000 square feet (ft²), up to approximately 5 feet thick at some locations; it was estimated to affect between 2,800 and 5,000 cubic yards of the vadose zone.

The LNAPL was characterized as having more of a diesel range fraction than a gasoline range fraction based on analytical results. It contained benzene, toluene, ethylbenzene, and xylenes, as well as a number of SVOCs and metals, including lead. The LNAPL was also classified as a hazardous waste based on its ignitability while not exceeding the toxicity characteristic leaching procedure (TCLP) limits.

Nature and Extent of Groundwater Contamination

The groundwater sample contained elevated concentrations of organic (VOCs and/or SVOCs) constituents and metals. PCBs were not detected in groundwater.

The groundwater samples collected from all wells monitoring groundwater above the peat contained organic (VOCs and/or SVOCs) constituents and metals at concentrations that exceeded the New Jersey standard for Class IIa groundwater criteria. These results suggest there is contamination by both organic compounds and metals in groundwater above the peat. Although the number of wells monitoring groundwater below the peat is limited, organic compounds exceeding criteria were detected in one of these wells, and metals exceeding criteria were detected in all four wells, suggesting metals contamination below the peat.

Isoconcentration maps of total VOCs and total chlorinated VOCs (CVOCs) for the groundwater above the peat show the greatest concentrations are encountered in the areas of the former lagoon and refinery. VOCs concentrations above criteria extend in the groundwater flow direction to the I-280 cloverleaf and to near Harrison Turnpike east of the landfill. On the west side of the landfill, VOC concentrations above criteria do not appear to have reached the boundary of the site, although a VOC plume extending in this direction can also be seen from the data. The total VOCs and total CVOCs isoconcentration contours maps for the groundwater below the peat show a decrease in the area of highest VOC concentrations, as well as a decrease in the total VOC concentrations in groundwater below the peat when compared to groundwater above the peat. VOC concentrations above criteria (benzene) are seen in the most downgradient deep well at the site at the tip of the VOC plume estimated below the peat.

The total SVOCs isoconcentration map for the groundwater above the peat shows the highest concentrations found between the areas of the former lagoon and refinery with contamination extending in the direction of groundwater flow to the I-280 cloverleaf (individual SVOCs were detected below criteria) to near Harrison Turnpike (individual SVOCs were detected above criteria). The total SVOCs isoconcentration contours map for the groundwater below the peat shows a decrease in the area of highest SVOC concentrations, as well as a decrease in the total SVOC concentrations in groundwater below the peat when compared to groundwater above the peat. SVOC contamination above criteria (bis-2-ethylhexyl phthalate) is seen in the most downgradient deep well at the site at the tip of the SVOC plume estimated below the peat.

A definable metals plume was not encountered at the site. Elevated metal concentrations were, however, observed in the strongly reduced portions of the VOC plume around the source area.

The groundwater data do not indicate that the landfill is acting as a source of site contamination. Specifically, a groundwater plume does not appear to originate from underneath the landfill. Thus, while the landfill exists at the site and is identified as a potential historic source, it may be composed—as the historic information indicates—of inert debris (for example, construction/demolition/household), which does not appear to contribute to chemical contamination at the site.

Nature and Extent of Contamination in Surface Water

The surface water samples collected at all ten surface water sampling locations contained organic compounds and metals. PCBs were not detected.

The surface water samples collected at all ten surface water sampling locations contained organic compounds and metals (predominantly lead) at concentrations above the lowest surface water quality and ecological criteria. These results suggest there is contamination in surface water at the site. Other than the consistent occurrence of VOCs above the lowest surface water quality criteria in the drainage ditch that runs along the south border of the site, a clear pattern of the occurrence of surface water contamination in relation to historic sources could not be established.

Nature and Extent of Contamination in Sediments

The sediment samples collected at all Phase 1 sampling locations (including the two background locations) contained organic compounds and metals.

The sediment samples collected at all sampled locations contained organic compounds and metals (predominantly lead) at concentrations above applicable criteria (direct contact or ecological criteria).

These results suggest that there is contamination in sediments at the site, with the PAHs predominantly exceeding criteria. The highest contamination was found within the footprint of the former lagoon.

Two sediment samples were collected in 1999 from an offsite area that was thought to be unaffected by the site. Both samples contained four PAHs above criteria, although the concentrations were lower than the concentrations detected at most onsite locations. These results suggest that while PAHs, which are known to be ubiquitous in urban environments, are occurring in the area around the site, site operations may have resulted in higher PAH contamination at the site.

Total PCBs were also detected above applicable criteria (direct contact or ecological criteria).

Human Health Risks Posed by the Site

The validated analytical data were screened against human health risk-based concentrations to determine if the chemicals of concern may pose a risk to human health. The results of this screening indicated that contaminants from all classes of organic compounds and metals present a human health concern in all the media at the site.

Ecological Risks Posed by the Site

Several contaminants of potential concern were identified as presenting ecological risk concerns by direct exposure screening (surface soil, sediment, and surface water) and by food-web exposure modeling (surface soil). While further consideration of these potential ecological risks may be warranted, it should be recognized that the habitats on the site have been highly disturbed by past activities and provide only very limited viable habitat for ecological receptors. Contaminants of concern were found at concentrations above ecological criteria in both surface water and sediment at the site.

1.3 Phase 2 Focused Remedial Investigation

1.3.1 Objectives of Focused Phase 2 RI

The general objectives of the Focused Phase 2 RI are to investigate the following:

- LNAPL source area
- Former landfill

Completing the Phase 2 RI would allow for the evaluation of remedial alternatives and the implementation of an IRM for the LNAPL, and confirmation that the landfill does not represent a source to groundwater contamination at the site.

LNAPL observed in monitoring wells and residual LNAPL in soil pores continue to contribute to soil and groundwater contamination at the site. While the Phase 1 groundwater data suggest that the landfill is not a source of the observed contamination, there is no information, other than anecdotal, on the landfill's content. The focused Phase 2 RI collected the data necessary to delineate the LNAPL and confirm that the landfill is not a source of groundwater contamination. An IRM can then be developed based on the results of this focused Phase 2 RI (including pilot testing of selected technologies) and a focused feasibility study (FFS) which will evaluate appropriate remedial alternatives.

During IRM implementation, time series data can be evaluated to assess changes in LNAPL thickness in monitoring wells and groundwater contaminant concentrations as the primary source of site contamination (i.e., the LNAPL) is being removed. At the end of the IRM, confirmatory soil samples can also be collected to estimate the chemical concentrations remaining in soils. These data can then be compared to applicable or relevant and appropriate requirements (ARARs) and used to evaluate the need and scope of additional investigation activities (e.g., additional groundwater investigation). These data will also support a comprehensive assessment of the human health and ecological risks associated with residual contamination remaining after the IRM, and the appropriate remedial alternatives for this contamination. If subsequent remedial efforts are deemed necessary,

these efforts can be more cost-effectively implemented since the IRM would have remediated the primary source of site contamination—the LNAPL.

The specific objectives of the Focused Phase 2 RI are as follows:

1. Delineate and assess the mobility of the LNAPL observed during the Phase 1 RI in the former lagoon area and in the former refinery area.
2. Confirm that, as suggested by the Phase 1 groundwater sampling results, the landfill (believed to contain construction debris based on historic information) does not constitute a source of groundwater contamination.
3. Collect information to support an FFS of remedial technologies for LNAPL. This would include performing pilot testing to support evaluation of the remedial technologies that appear to be applicable to the current site conditions.

The general technical approach utilized for each area to be investigated is described below. In addition, site preparatory activities that were needed to provide access were performed and are also described below.

1.3.2 Scope of Focused Phase 2 RI

The Focused Phase 2 RI included the following activities:

- Site visit by the core project team to review current site conditions and begin implementation planning.
- Preparation of planning documents to guide the delivery of the work. These included:
 - Quality Assurance Project Plan (CH2M HILL, 2007d)
 - Sampling and Analysis Plan (CH2M HILL, 2007e)
 - Contractor Quality Control Plan (CH2M HILL, 2007a)
 - Health and Safety Plan (CH2M HILL, 2007c)
 - Site Management Plan (CH2M HILL, 2007f)
- Preparation of subcontractor scopes of work and procurement of subcontractors for the needed services, facilities, and supplies.
- Preparation of documentation to demonstrate that the following activities are performed in accordance with the substantive requirements of the applicable regulations: road construction within wetland areas, discharge of water from dewatering during the construction of the air/bio sparge pilot test trench, and air emissions from the air/bio sparge pilot test. For the latter two of these, NJDEP issued permits. The performed activities complied with the permit requirements, which represent substantive requirements with which activities at Superfund sites are required to comply.
- Mobilization of field facilities, equipment, and supplies.
- Site preparation, including vegetation clearing, road construction, and clearing areas for subsurface utilities. Vegetation clearing was necessary to remove the heavy underbrush and phragmites to provide access to areas of the site targeted for investigation. Construction of temporary roadways was necessary because of the extensive flooding at the site following rain events. The temporary roadways provided access to the former lagoon area and other areas of the site that would otherwise not be accessible because of flooding. A surface geophysical survey was performed in the clover leaves of I-280 to

determine if subsurface utilities are present. The New Jersey-One Call system was also utilized.

- Landfill investigation consisting of trenching within the landfill for visual inspection of its contents. Soil samples for characterization purposes were also collected at pre-determined spacing within the trenches and from several areas where staining/odors were observed. Several waste materials found in the landfill were also sampled. Because the objectives of this investigation were to observe, and not remediate, the contents of the landfill, wastes observed in the landfill were left within the landfill unless there was a strong indication based on visual observations that the waste may still be releasing contamination to the environment. Two compromised drums were noted to fit this definition and were removed from the landfill, overpacked, sampled, and sent for offsite disposal.
- LNAPL investigation consisting of laser induced fluorescence (LIF) investigation and a limited soil boring program to supplement the results of the LIF investigation. The results of this investigation were used to define the extent of recoverable and residual LNAPL, and to identify priority target areas for remediation. The LIF technology was used to delineate the extent of the LNAPL beginning in the former lagoon area and former refinery area, and extending into the Rt. 280 cloverleaf. The LIF tool, an in situ evaluation system, provided real-time, semi-quantitative graphical data. Results at each location were used to make decisions on the locations of subsequent locations in order to achieve delineation of the LNAPL. The limited soil boring program supplemented the LIF results and included collecting and logging soil cores to ground truth the observed LIF responses and collecting soil cores for specialty laboratory testing. Grab soil samples were also collected to evaluate the LNAPL in terms of its potential mobility/recoverability and its leachability of contaminants to groundwater.
- LNAPL recoverability test to support the evaluation of treatment technologies during the FFS for remediation of the mobile LNAPL. These recovery tests included purging of free product from a well and observing the rate of drawdown in adjacent monitoring locations, and the rate of product accumulation in the pumped well. The test began and ended with complete rounds of water level and LNAPL thickness measurements. A pre-test was conducted to design the recovery system. During the test, pressure transducers were installed in select wells to monitor the rate of product and water accumulation in the wells. Product recovery measurements were collected during each test until at least 80 percent of the original product thickness in the well recovered, or for up to 8 hours.
- Pilot scale air/bio sparge test to support the evaluation of bio-sparging for the bioremediation of residual LNAPL. For the test, a horizontal sparge well approximately 30 feet long to a depth of about 10 feet bgs was constructed and five temporary 1-inch-diameter well points installed using direct push technology to monitor groundwater conditions in the area of the test. The sparge test was then conducted by first starting out at low injection rates, demonstrating steady-state conditions are achieved, and then stepping up to a higher injection rate. Field parameters in groundwater were monitored during the test and groundwater samples were collected from the temporary well points before and at the end of the test for analysis for VOCs and bacterial counts. The air/bio sparge field test continued for 10 days.
- Investigation-derived waste (IDW) management, characterization and disposal.

1.3.3 Limitations of Focused Phase 2 RI

By the nature of its objectives and scope, the Focused Phase 2 RI results must be viewed within certain limitations, of which the major ones are as follows:

- The information collected during this investigation depicts subsurface conditions only at the specific locations and times tested. Subsurface conditions (including physical LNAPL properties and characteristics) at other locations and times may differ from the conditions at the tested locations and times.
- Extrapolation of data over long distances between data locations (e.g., groundwater and LNAPL contours), when done, was based on the best available knowledge and professional judgment. Actual conditions may differ from the inferred depiction.
- The LIF technology provides screening-level qualitative data that can be used to assess the contamination in one area of the site relative to another, but does not quantify contaminant concentrations for comparison to regulatory levels or to assess the risks posed by the site.
- The pilot testing performed over a relatively short period indicated that the air sparge technology can promote aerobic conditions that typically support aerobic degradation of petroleum contamination. More significant biological growth (and associated decreases in petroleum contamination) that would result from a long-term application of this technology cannot, however, be predicted based on the pilot test because of its relatively short duration.
- For the LNAPL, the *New Jersey Administrative Code* (N.J.A.C.) 7:26E Subchapter 6.1 (d) states that free and/or residual product needs to be treated or removed when practicable, or contained when treatment or removal are not practicable. Natural remediation (e.g., monitored natural attenuation or MNA) of free and/or residual product will not be considered by NJDEP. Based on these requirements, a remedial action objective (RAO) for the LNAPL could be defined as the removal of recoverable LNAPL and treatment of the residual LNAPL. Definitive RAOs will be proposed for the LNAPL in the FFS.
- The results of the LNAPL mobility and recoverability assessment must be interpreted within the context of the assumptions used for the calculations. All practical effort was made to present conservative parameter values so that the result may possibly be an over-estimate of the potential mobility and recovery of the LNAPL.
- Following implementation of the IRM and the recovery/treatment of the LNAPL to the degree practicable by the technology(ies) selected in the FFS, the NJDEP soil and groundwater cleanup criteria, or other criteria established by USEPA can be used to assess whether the chemical contamination remaining in the soil and groundwater within the area covered by the IRM requires additional remediation efforts. Confirmatory sampling to assess soil and groundwater concentrations remaining after the IRM would, therefore, be needed at the end of IRM implementation. It may be appropriate for this sampling to also include testing to determine the leachability of contaminants remaining after the implementation of the IRM, as some LNAPL may be left in the soil pores at the end of the IRM. The results of this testing after treatment would then be compared to the testing planned to assess the leachability of contaminants as part of this focused RI.
- The results from the confirmatory sampling and leachability testing following the IRM can be used to support a human health and ecological risk assessment for the site and

support decisions on path forward to site closure. Note that the area covered by the IRM (the area where LNAPL treatment is targeted) will likely not cover the entire site. Chemical contamination in areas not covered by the IRM would need to be included in subsequent considerations.

- The Focused Phase 2 RI collected data within identified source areas at the site. Data were extrapolated and assumed to represent conditions in areas where actual data were not obtained. Site operations may have resulted in areas or pockets of contamination throughout the site that are not represented by the extrapolations made for the purpose of this TM.

1.4 Purpose and Organization of this Technical Memorandum

The purpose of this TM is to present and interpret the data collected during the Focused Phase 2 RI. This TM comprises this introduction and nine further sections:

- **Section 2—Site Preparation:** Summarizes mobilization and demobilization activities including subcontract procurement, field facilities, and geophysical investigation for subsurface utilities; vegetation clearing; and road construction.
- **Section 3—Landfill Investigation:** Describes the implementation and results of the landfill investigation, including trenching and sampling.
- **Section 4—Laser Induced Fluorescence Investigation:** Discusses the implementation and results of the LIF investigation, including associated sampling.
- **Section 5—Pilot Test – LNAPL Recovery Test:** Describes the LNAPL recovery test including the hydraulic characteristics of the material and its mobility and potential recoverability based on these field test results. Also described are the chemical characteristics of the LNAPL based on the performed sampling.
- **Section 6— LNAPL Mobility and Recoverability Evaluation:** Describes the LNAPL hydraulic characteristics based on specialized laboratory testing and presents an evaluation of its mobility and feasibility of its recovery based on the performed laboratory testing.
- **Section 7—Pilot Test Air/Bio Sparge:** Describes the air/bio sparge pilot test and the feasibility of this technology for treating residual LNAPL at the site. Also described are the results of the groundwater sampling performed to assess the applicability of this technology to site contamination.
- **Section 8—Investigation Derived Waste Management:** Describes IDW management, sampling, characterization, and disposal.
- **Section 9—Conclusions and Recommendations:** Presents an overview of the investigation results and preliminary recommendations.
- **Section 10—References:** Lists the reports and references used during the preparation of this TM.

SECTION 2

Site Preparation

Section 2.0 describes the following:

1. Mobilization and demobilization activities at the start and end of the field investigation
2. Geophysical investigation completed to detect the presence of subsurface utilities
3. Clearing of vegetation to provide access to overgrown areas
4. Construction of temporary roadways to provide access to potentially flooded areas

2.1 Mobilization and Demobilization

2.1.1 Field Support Equipment, Supplies, and Facilities and Subcontract Procurement

Prior to mobilization to the field, equipment, supplies, and facilities were identified that were necessary to support the investigation activities. Technical specifications for the required support equipment and services were developed, and subcontractors were identified and procured through a competitive bid process.

The following field facilities, services, and subcontracts were procured:

- Temporary office trailer and equipment storage box (conex sea-container)
- Porta John
- Trash service
- Printer/scanner/copier
- Generators for the office trailer and air sparging equipment
- A licensed electrician to connect and disconnect power supply from the generators
- Sampling equipment, monitoring instruments, and supplies
- Computer and printer
- Monitoring equipment, health and safety supplies, and global positioning system (GPS) survey equipment
- Subcontractor for the location of subsurface utilities
- Subcontractor for vegetation clearance, temporary roadway construction, air/bio sparge pilot test trench construction, and landfill test pitting
- Subcontractors for LIF and drilling (including installation of temporary well points)
- LNAPL recovery testing equipment and supplies
- Air/bio sparge pilot test equipment and supplies
- Intact core and LNAPL fluid laboratory specialty testing
- Synthetic precipitation leaching procedure (SPLP) and LNAPL chemical characterization laboratory
- Air/bio sparge groundwater bacterial analyses laboratory

A Property Control Representative (PCR) was designated for the project. The PCR was responsible for maintaining documentation on equipment rental and consumable purchases in conformance with the operating procedures for government property administration established by Far Part 45 and CH2M HILL's approved Government Property System.

2.1.2 Mobilization

Mobilization to the field was initiated on January 21, 2008, and included the following activities:

1. Overseeing delivery of the field support facilities and services to the site
2. Setting up the onsite field office trailer
3. Identifying, assembling, loading, transporting, unloading, and arranging the equipment at the site for each of the identified field events including the landfill investigation with soil sampling, LIF investigation with confirmatory soil sampling, LNAPL recovery test, air/bio sparge pilot test with groundwater sampling, and two rounds of LNAPL and groundwater level measurements

2.1.3 Demobilization

The demobilization activities were performed April 21 and 22, 2008, and included removing equipment and facilities from the site at the conclusion of the field investigation. The project files were removed from the temporary field office trailer, taken to the CH2M HILL office in Parsippany, New Jersey, and organized for subsequent project phases.

2.2 Geophysical Investigation (utility delineation)

A utility delineation markout was performed by Enviroscan, Inc. of Lancaster, Pennsylvania, on January 23 and 24, 2008, prior to performing intrusive LIF investigation work in the cloverleaf area of I-280. This subcontracted work was augmented by utilizing the New Jersey One-Call system. Surface geophysical instruments utilized electromagnetic techniques including an EM-31, ground penetrating radar (GPR) and magnetometer (MAG) to detect and mark the location of buried utilities within the entire area of the I-280 cloverleaf. Based on the results of the survey, the locations of water, electric, and storm sewer lines were marked in the cloverleaf. No utilities were encountered by the drill rig during the intrusive LIF investigation activities.

The NJ One-Call utility delineation service was utilized to identify onsite utilities. Of note, Phase 2 activities occurred within the same areas where the Phase 1 activities occurred. The locations of the Phase 1 activities were cleared for subsurface utilities by the same subcontractor utilized during Phase 2 to clear utilities in the cloverleaf.

2.3 Vegetation Clearing

To facilitate access to the areas of the site where Phase 2 activities were planned, Lewis Environmental was subcontracted to cut and clear standing vegetation at the site. Vegetation clearing was performed January 21 to 24, 2008. The areas of the site where the vegetation was cleared included:

- Along the paths of the two exploratory trenches within the landfill
- To the east and north of the landfill to facilitate general access for work crews and equipment
- The areas where the temporary roadways were constructed
- Along the top of the north section of the soil berm bordering the highway entrance ramp

Vegetation over the landfill generally consisted of 15-foot-tall phragmites grass, while vegetation to the north and east of the landfill generally consisted of tall grass, underbrush, and small shrubs and sapling trees. The vegetation on the soil berm consisted of phragmites grass and trees. The clearing activities were performed using a multi-terrain loader (tracked skid steer) with a brush cutter attachment. In addition, select trees on the soil berm were cut using a chain saw.

The cut vegetation was left in place as ground cover to improve ground conditions, and reduce soil erosion and transfer of mud as a result of repeated traffic. The trees were staged at designated locations removed from the main areas of investigation. This represents a deviation from the planned work and did not present a tick-habitat concern because the work was performed during the winter months.

Appendix 1 contains a table summarizing the areas of the site where vegetation was cleared and also presents photographs from before and after the clearing activities.

2.4 Temporary Gravel Road Construction

During the Phase 1 RI, several areas of the site were found to be inaccessible to machinery and equipment because of areas of soft, wet, muddy ground and standing water. Portions of the Focused Phase 2 RI were designed to fill data gaps as the result of this inaccessibility. To provide access to these areas of the site, temporary gravel roads were constructed by Lewis Environmental between January 22 and 29, 2008.

Figure 1-3 shows the location of the temporary gravel roads and also depicts the locations of other activities completed during this focused Phase 2 investigation, including the locations of the landfill trenches, temporary piezometers installed to support LNAPL recovery testing, air/bio sparge pilot testing, and an index of map quadrangles showing additional site detail. These quadrangles are presented in Figures 2-1 through 2-7 where expanded views show details of the constructed roadways. Two types of road construction activities were performed:

1. Portions of the existing dirt roads that were known from the Phase 1 activities to flood or degrade to soft mud with heavy vehicle traffic were improved so heavy vehicle traffic could utilize them during Phase 2 and any additional future investigation activities. These improvements brought up the existing grade so that the roadways are no longer subjected to flooding or muddy conditions.
2. New roads were constructed in areas of the site prone to flooding, or through areas containing no vehicular access pathways.

Site roadways were designed to support truck traffic averaging GVW 52,000 pounds (a typical drill rig) and are intended to last for at least 2 years. Low-lying areas and depressions within the pathway of the road were backfilled and leveled with stone fill before beginning roadway construction. The dirt road improvements consisted of laying Mirafi 1100n geotextile fabric and overlaying it with a thickness of 3 to 6 inches of 2-inch-diameter stone. New roadway construction consisted of overlaying the geotextile fabric with a thickness of 12 to 24 inches of rip-rap stone (4 to 12 inches in diameter) as a base layer. A second layer of geotextile was laid over the rip-rap to contain a top layer of 2-inch-diameter stone for the road surface.

A CAT 953 track loader was utilized to install and grade certified clean crushed stone. Appendix 1 contains the clean stone certification. A total of 600.03 tons of 2-inch-diameter

stone was utilized for road surfaces and 986.52 tons of 6- to 12-inch-diameter rip-rap stone was utilized as road base for the new road construction. All roads were constructed with a nominal 12-foot width. Approximately 280 linear feet of existing roadways were improved and approximately 878 linear feet of new roadways were constructed. In addition, one 45-foot by 37-foot turnaround was constructed. The roadway improvements included two 50-foot-long access ramps to provide construction entrance access to the landfill.

Appendix 1 contains a table summarizing the details of road construction (e.g., width, stone layer thicknesses) and a copy of the clean fill certification for the stone, and also presents photographs from each step of the road construction activities.

Spatial information of interest (e.g., centerline and perimeters of roads) was recoded at regular intervals using a GPS to an accuracy of 0.25 meters (10 inches). The coordinate information is also provided in Appendix 1.

Of note, a new roadway needed to be constructed within the footprint of wetland Area 1. This area is situated within the footprint of the former lagoon – the main source area targeted for investigation during this Phase 2 RI. To document the area of wetlands affected by the construction of this roadway, the outline of the roadway was surveyed using the GPS, and the coordinate information is also provided in Appendix 1.

2.5 Summary

Site preparation activities included the following:

- Mobilization of field, equipment, supplies, and facilities.
- Markout of utilities in the cloverleaf area of I-280 and contacting the New Jersey One-Call utility delineation service prior to start of field activities.
- Clearing standing vegetation along the paths of the two exploratory trenches within the landfill, to the east and north of the landfill, along the layout of the planned temporary roadways, and along the top of the north section of the soil berm bordering the highway entrance ramp. The cut vegetation was left in place as ground cover to improve ground conditions and reduce soil erosion and transfer of mud as a result of repeated traffic.
- Constructing temporary roadways designed to support truck traffic averaging GVW 52,000 pounds (a typical drill rig) and intended to last for at least 2 years. Two types of road construction activities were performed:
 - Portions of the existing dirt roads were improved to bring them to the existing grade so they would no longer be subjected to flooding or muddy conditions.
 - New roads were constructed in areas of the site prone to flooding and in areas containing no existing roadways.

SECTION 3

Landfill Investigation

Section 3 describes the following:

1. The purpose and scope of the landfill investigation
2. The historical information available on the landfill
3. Implementation of the landfill investigation activities, including:
 - Trench excavation activities
 - Sampling for general characterization of the landfill's contents
 - Sampling associated with features of interest identified during the trenching activities
4. The results of the landfill investigation activities, including a description of the landfill's contents and analytical results from sampling of landfill contents and interstitial materials.

3.1 Purpose and Scope

The Phase 1 RI identified the onsite landfill as one of three potential sources of site contamination.

Based on historic aerial photographs, the landfill appears to have begun operations around 1959. By the time operations appear to have ceased—approximately 1979—the landfill is seen on aerial photographs to have reached its current size of approximately 7 acres. While the general location of the landfill can be identified at the site, its exact limits are poorly defined because of the nature of the feature and the way topography changes gradually across the site, and the presence of debris over the entire site, not only within the footprint of the landfill.

Limited historical information is available on the operations and contents of the landfill. The landfill was not permitted, and no operational records are available to provide details on the wastes deposited in the landfill. Some characterization of the wastes in the landfill was derived from the soil boring logs for three monitor wells installed in the landfill (investigation completed in 1990 by Killam Associates, Hazard Ranking System Documentation Package, Diamond Head Oil Refinery Division, Kearny, Hudson County, N.J.; CERCLIS ID No. NJD092226000, July 2000). Based on these logs, the landfill is believed to contain inert demolition debris such as concrete, metal, brick, glass, timbers, plastic, and soil.

The Phase 1 RI did not investigate the contents of the landfill. Its results did not indicate, however, a groundwater plume originating from underneath the landfill, thus suggesting that the landfill may not be acting as a source of site contamination—results consistent with landfill contents of inert demolition debris. Thus, while the landfill exists at the site and is identified as a potential historic source to site contamination, it may be composed—as the historic information indicates—of inert debris (for example, construction/demolition/household), which does not contribute to chemical contamination at the site.

The objectives of the landfill investigation conducted during this Phase 2 RI were to characterize materials in the landfill. The results of this investigation were then used, together with the results of the Phase 1 RI and the available historic information, to further evaluate whether the landfill may serve as a source of site contamination. Furthermore, remediation of any encountered buried drums or other waste was not the objective of the landfill investigation.

The general approach for completing the landfill investigation consisted of clearing vegetation from the surface of the landfill to allow excavation of two continuous test trenches through the contents of the landfill. Sampling was also planned to characterize the chemical composition of the landfilled materials.

Trenching began outside the perimeter of the north end of the landfill to establish the depth of the native materials and the depth to groundwater. The two planned trenches were excavated to varying depths because of the irregular shape and contents of the landfill, targeting the full thickness of the landfill or the groundwater table, whichever was encountered first. The trenches were used for visual inspection of the contents of the landfill and were installed in segments such that excavations were not left open at the end of the work day. Workers did not enter the trenches. In addition to visual observations and field monitoring of the materials in the excavation, soil samples were collected at both predetermined intervals and from locations biased toward stained soil or elevated field screening results. Samples were also collected from features of interest encountered during the excavation activities—such as not readily identifiable waste materials (e.g., resin-like material). Samples of the landfilled materials were analyzed for both organics (full target compound list [TCL] analysis) and target analyte list (TAL) metals through USEPA's Contract Laboratory Program (CLP). Samples of features of interest encountered during the excavation activities were analyzed by a subcontracted laboratory (Chemtec) also for both organics and metals.

The locations of the two test trenches were selected based on an analysis of a series of historic aerial photos from 1942 to 1990 compiled and analyzed by USEPA in a document titled "Aerial Photographic Analysis of Diamond Head Oil Refinery Division, Kearny, N.J., July 2002." These photographs and the accompanying interpretations were examined to identify features of interest on the aerial photographs such as staining, dumping, and development of dirt access roads during the operational life of the landfill, along with observations of the overall growth of the landfill over time. The transects for the two test trenches were selected based on the reviewed information and to provide areal coverage over the estimated area of the landfill.

3.2 Summary of Available Historic Information on the Landfill

The available information on the landfill presented in this TM is derived from the following sources:

- Limited investigations of the landfill in 1990 and 1991, the results of which are presented in two reports listed below. These two reports are themselves incorporated into the "Health Consultation, Site Visit Report, Diamond Head Oil Refinery Division, Kearny, Hudson County, New Jersey, EPA Facility ID: NJ092226000," dated May 11, 2001, and prepared by the U.S. Department of Health and Human Services.
 - *Environmental Site Characterization of Block 285, Lots 3, 4, and 5 Kearny, New Jersey*, prepared by Killam Associates Consulting Engineers, August 1990.

- *Final Draft, Site Inspection Report, Diamond Head Oil Refinery Div., Kearny, New Jersey*, Volume 1 of 2 prepared under Work Assignment No. 019-2JZZ Contract No. 68-W9-0051, December 31, 1991.
- Historical aerial photographs of the landfill spanning from 1942 to 1990 assembled by USEPA in a report titled “Aerial Photographic Analysis of Diamond Head Oil Refinery Division, Kearny, New Jersey, July 2002.”

Based on the available historical information, no test pits have been installed up to the time of this Phase 2 RI to investigate the nature of the landfilled materials. Six soil borings were installed, however, into the landfill during historic investigations in 1990. The logs for these borings provide some indication on the nature of the materials in the landfill.

3.2.1 Summary of Historic Landfill Investigation Activities

The following information is from the “Environmental Site Characterization of Block 285, Lots 3, 4, and 5 Kearny, New Jersey” prepared by Killam Associates Consulting Engineers, August 1990.

Killam Associates Consulting Engineers performed the activities below for the Hudson Meadows Urban Renewal Development Corporation to investigate the nature of the landfill in support for site redevelopment plans.

- **Terrain Conductivity Survey**—This survey was conducted on June 19, 1989, using an EM-31 terrain conductivity meter to determine the presence of buried metallic objects. The survey covered an approximate area of 11 acres extending over the landfill, as well as the area of the former refining operations. A 100-foot by 100-foot grid pattern was used for the survey. Along the grids, measurements were collected at 25-foot increments (i.e., no data are available within each 100-foot by 100-foot grid quadrant). The effective vertical investigative depth of the instrument was 6 meters.
- The report noted that because of the shallow water table and because “the landfill was developed over marsh deposits,” high conductivity readings were expected and measured across the site. Within these high overall conductivity readings, the report noted that “...anomalies which would indicate the possible presence of buried metallic objects ...were (not) evident. ... the terrain conductivity survey proved unremarkable.” The results of this survey should be viewed within the limitations of the technology in that the high overall conductivity readings could be masking the presence of metal anomalies. It should be noted that a similar situation may occur in an electromagnetic (EM) survey performed with current EM technology. Since the actual data from the 1989 survey is not available, however, the statement that metal anomalies were not identified within the high overall readings cannot be verified. The grid used is also relatively large and conceivably could have missed buried drums.
- **Soil Gas Survey**—This survey was conducted on June 19, 1989, to determine the presence of volatile organic gases from materials that have been landfilled at the site. The survey covered the same area and grid pattern as the terrain conductivity survey mentioned above. Using the 100-foot by 100-foot grid pattern, 0.5-inch-diameter by 30-inch-deep borehole was created using an impact probe. The boreholes were then screened using a flame ionization detector and photoionization detector.
- The OVA results indicated that methane was present across the surveyed area. The report concluded that the methane is being produced from to the decomposition of

natural and/or landfill materials at the site. In general, the methane concentrations were the lowest on top of the landfill from where they increased to the west along the west border of the site and to the east in the refinery and former lagoon areas of the site. The measurements in these areas were taken in what may be described as "native" site materials as opposed to "landfilled materials" (possibly construction debris) in the landfill area.

- The HNU results indicated that concentrations of VOCs other than methane are low on top of the landfill and higher in the former lagoon area and in the northwest corner of the site. Of note, the Phase 1 RI identified elevated groundwater concentrations in the northwest corner of the site. These concentrations could not be correlated with the areas where historic operations took place at the site.
- Soil Borings and Monitoring Wells—Three soil borings (SB-1, SB-2, and SB-3) and three monitoring wells (MW-1, MW-4, and MW-5) were installed within the former landfill in October 1989. The soil boring logs indicate miscellaneous fill material including brick, glass, plastic, wood, cinders, and other miscellaneous materials from 7.5 feet bgs to approximately 18 feet bgs. Petroleum odor and staining were also noted, however, in all the borings. It is possible that petroleum was used to suppress dust during landfilling operations or that oily wastes/debris were deposited directly into the landfill.
- Two soil samples from each soil boring were collected and analyzed for petroleum hydrocarbons (PHCs) and priority pollutant plus 40 (PP+40). The report states that petroleum hydrocarbons, total VOCs, total SVOCs, and several metals were above the standards used at the time to evaluate the data. The data tables in the report are illegible and it is not possible to determine the depths at which the samples were collected and compare the results to current NJDEP criteria to evaluate their significance. Two rounds of groundwater samples (November 1989 and January 1990) were also collected. The report states that PHCs, total and individual VOCs, total and individual SVOCs, and several metals were above the standards used to evaluate the data. As with the soil data, the data tables in the report are illegible, and it is not possible to compare the measured values to current NJDEP criteria.

The following information is from *Final Draft, Site Inspection Report, Diamond Head Oil Refinery Div., Kearny, New Jersey*, Volume 1 of 2 prepared under Work Assignment No. 019-2JZZ Contract No. 68-W9-0051 prepared by HALLIBURTON NUS Environmental Corporation, December 31, 1991.

A site inspection was performed by HALLIBURTON NUS Environmental Corporation for the EPA under the Field Investigation Team (FIT) contract. The site inspection estimated the size of the landfill at 7 acres. The report was presented as a site summary and recommendations section and associated backup sections referred to as "Parts." Part II, "Waste Source Information: Waste Unit—Landfill" describes the landfill.

- The report states that the operators of the landfill and the substances deposited in the landfill are unknown. The report goes on to stating that there are "no known reports of hazardous substances being deposited in the landfill," however.
- The report refers to surface soil samples collected by NJDEP at the site in May 1985 (Please see Phase 1 TM for a summary of the results from this sampling [CH2M HILL, 2005]). The results indicate various SVOCs and select metals. The information provided in the report (Part III and Reference No. 24) is not, however, sufficient to determine which samples were collected from the landfill.

- The site report noted a “solid caramel colored, translucent material on the ground surface in the landfill area between monitoring wells MW-4 and MW-5. This substance was assumed to be a resin of some type.” A sample of this material was collected in July 1991 and analyzed for TAL organic and inorganic compounds. Results of the material “indicated that no contaminants were detected in the material.”

3.2.2 Summary of Historical Aerial Photography

The following summary of the operational life of the landfill was prepared based on the historical aerial photographs spanning from 1940 to 1990 contained in the “Aerial Photographic Analysis of Diamond Head Oil Refinery Division, Kearny, New Jersey, prepared by the USEPA Environmental Sciences Division, Landscape Ecology Branch, January 2002.”

- In 1940, the Diamond Head site was undeveloped wetlands.
- Between 1940 and 1951, the eastern portion of the site began to be developed and the western portion of the site (occupied by the current landfill), consisted of wetlands in the southern portion and fill area in the central and northern portion.
- In 1959, the aerial photographic analysis refers to the northern portion of the current landfill as a fill area or debris/refuse.
- In 1966, it appears that landfilling was occurring in the southern section of the current landfill, which appears to have been cleared of vegetation. This area was referred to as a fill area with an access road leading to it.
- In 1973, the access road seen in 1966 was still evident. The southwestern portion of the current landfill appears to have been excavated. To the west of the excavation area, there is an area of dark material/stain.
- In 1976, the access road is slightly evident and the entire landfill appears to have been covered with vegetation.
- In 1978, the landfill appears to have been graded.
- In 1979, the landfill increased in size and appeared to have been capped. The aerial photographic analysis states that “pools of liquid, staining, and refuse and/or debris are visible along the western site boundary at the base of the west side wall of the landfill.”
- In 1980, the landfill appears similar to the 1979 aerial photograph.
- In 1982, the landfill appears to be covered with vegetation. No additional changes are observed.
- In 1990, no significant changes are observed.

3.3 Implementation of Landfill Investigation Activities

3.3.1 Trench Excavation Activities

The landfill investigation was performed between February 1 and 18, 2008. Lewis Environmental excavated the exploratory trenches utilizing a track-mounted CAT 321C hydraulic excavator.

The general layout of the two landfill investigation trenches, Landfill Trench-East (LTR-E) and Landfill Trench - West (LTR-W) is shown in Figure 1-2, which also shows other Focused Phase 2 RI activities. Approximately 900 linear feet were excavated for Landfill Trench-East and 870 linear feet were excavated for Landfill Trench-West. The excavations were installed in segments 10 to 15 feet in length (33 segments per trench) to manage slope stability and prevent collapse. Each segment was excavated and then backfilled before moving to the next segment. A "retaining wall" of 1-foot to 3-feet in width was preserved between trench segments to further manage slope stability. The trenches were excavated with a nominal width of 5 feet and varying depths. The objective of the investigation was to excavate through the full thickness of the landfilled materials or stop at the water table that would have destabilized the excavation. Because of the shallow water table at the site, the excavations were completed between 5 feet to 17 feet deep below the surface of the landfill. Detailed layouts for each segment, including segment identification, features of interest, and sampling points, are shown in Figures 3-1 through 3-6. A table summarizing individual trench segment details (length, width, depth) is also provided in Appendix 2.

The excavated spoils were staged on plastic, the spoils and trench photographed, and observations logged by a geologist. The spoils were scanned for organic vapors with a photoionization detector (PID) equipped with an 11.7 eV lamp, and the excavation was monitored for health and safety considerations with a multi-meter for lower explosive limit (LEL), hydrogen sulfide (H₂S), oxygen (O₂), carbon monoxide (CO), and organic vapors (PID). The presence of fill, debris, natural material, wastes, and indications of staining or contamination were noted. Soil samples were collected to characterize the landfill materials and are discussed in the next subsection. Appendix 2 contains landfill excavation logs and photographs of the excavations. Spatial information of interest (e.g., trench centerline, segment corners, locations of features of interest, sampling locations) was recorded using a GPS system to an accuracy of 0.25 meters (10 inches), and the coordinate information is provided in Appendix 2.

Following observation and logging, the materials were returned to the excavation in stages and compacted with the excavator bucket. Work was performed such that the sections of the trench were excavated and backfilled in the same day so that no excavations were left open overnight. During the excavation activities, silt fencing was utilized for erosion control, as needed, and dust control was not necessary because of the intrinsic moisture content of the spoils.

During the landfill trenching investigation, several drums and other features of interest were encountered. Because remediation of buried drums was not the intent of this investigation, the following decision process was used to address these when they were encountered:

- 1) when features such as drum "carcasses" were encountered that were already damaged and contained no materials, they were noted, described in the log, the location marked for GPS coordinates, and the feature was placed in the trench and backfilled with other excavated rubbish;
- 2) when features such as complete or partial drums were encountered that contained unidentified material or materials of concern or showed signs of contamination (e.g., high PID readings), they were noted, described in the log, the location marked for GPS coordinates, and the feature was removed and overpacked for characterization and offsite disposal; and
- 3) when uncontained unidentified materials were encountered, the materials were not removed from the landfill but a determination was made whether they should be sampled for characterization purposes.

3.3.2 Sampling Methodology

3.3.2.1 Characterization Sampling

To characterize the general chemical conditions within the landfill, five soil samples were collected from each trench path (total of 10 samples with associated quality control samples). These samples were spaced equally over the length of each excavation. Four additional samples were collected at locations where there was indication of potential contamination (e.g., elevated odors, PID readings, or staining). All four samples were collected within the west trench. The sampling locations are shown in Figure 1-2 and are also shown in the figures showing the landfill segment details—Figures 3-1 through 3-6. The soil samples were analyzed for full TCL and TAL analyses through USEPA's CLP. The VOC component of the samples was collected utilizing EnCore™ samplers. Details for the samples (sample ID, date, time, analysis performed, laboratory, etc.) are provided in Table 3-11

Results of samples analyzed through CLP are validated by USEPA. Validation involves the review of the data to assess their accuracy, precision, and completeness using the following standard procedures:

- Organic compounds—USEPA Region II Data Validation SOP for Statement of Work OLM04.2 (SOP HW-6 [revision 12] March 2001)
- Metals—USEPA Evaluation of Metals Data for the Contract Laboratory Program (SOP HW-2 [revision 11] Jan. 1992)

A full discussion of data qualifications is available with the data packages. The data packages are not included in this report because of their volume, but are kept in the project files.

In order to provide a perspective on the site-related constituents encountered in the landfill, constituent concentrations detected in the samples from the landfill were compared to the NJDEP Residential Direct Contact Soil Cleanup Criteria (RDSCC) and Nonresidential Direct Contact Soil Cleanup Criteria (NRDCSCC) (last revised in June 2, 2008, and available on the internet at <http://www.nj.gov/dep/srp/rs/>). While these standards are not directly applicable to the landfill media since contact with landfill materials is unlikely, they provide a comparative reference for the chemical concentrations.

Analytical results from sampling activities were managed using the database developed during the Phase 1 investigation activities in EQUIS 3.0 format.

3.3.2.2 Sampling Features of Interest

As described in greater detail in the results section of this report, five features of interest encountered during the landfill investigation were sampled. Two of the features consisted of crushed drums containing residual materials. While one did not show elevated PID readings, the drum was almost half full with the gelatin-like material and was, therefore, removed and overpacked for subsequent sampling and offsite disposal. The second drum showed the highest PID readings (1,352 parts per million [ppm]) measured during the landfill investigation and was overpacked for subsequent sampling and offsite disposal. Samples associated with these features were later sampled for full TCL and TAL analyses, ignitability, and corrosivity through a subcontracted laboratory (Chemtech). The other 3 features consisted of unidentified, uncontained materials. These materials were left where found in the landfill, but were also sampled for TCL and TAL analyses through the subcontracted

laboratory. The five features that were sampled included Features 2, 7, 13, 14, and 15, with Features 2 and 15 comprising the two features that were overpacked for offsite disposal.

Details for the feature of interest samples (sample identification [ID], date, time, analysis performed, laboratory, etc.) are provided in Table 3-1. Like the landfill characterization samples, the results of the analysis for the features of interest are compared to the NJDEP RDSCC and NRDCSCC to provide a prospective on the encountered contamination in the landfill. While these standards are not directly applicable to the media contained in the features of interest, they provide a reference point for the chemical concentrations measured in the samples. Because of the matrix of the media sampled and the screening nature of the analysis, the sampling results for the features of interest were not validated.

3.4 Results of Landfill Investigation Activities

3.4.1 Description of Landfill Contents

The majority of the landfill contents were observed to consist of municipal-type wastes with a lesser component of demolition-type debris. Appendix 2 contains photographs and excavation logs for each of the 66 trench segments that were installed. In general, the municipal-type waste consisted of glass and plastic beverage bottles, steel and aluminum cans from foodstuffs, residential and consumer papers including newspapers (the oldest noted were from 1959), and other glass, metal, plastic, wood, and cardboard-type materials typical of residential and consumer goods. Demolition-type debris were also observed including brick and concrete fragments up to 5 feet in diameter; wood products including timbers, planks, and tree stumps; metal including pipes, rebar, and flatiron; and general construction materials including shingles and sheet plastic. Industrial-type debris was also observed including steel, poly and fiber drums, and industrial resin or polymer-type materials intermixed with the general landfill refuse. When noteworthy industrial debris was observed, it was logged as unique features of interest.

Twenty-two features of interest were encountered throughout the landfill investigation (Figures 3-1 through 3-6). Table 3-2 provides a comprehensive summary of the 22 features of interest that were identified, and describes the details for each feature, including the location coordinates, description, whether the feature was sampled, and whether the feature was backfilled in the trench or overpacked for offsite disposal. The features generally consisted of crushed steel 55-gallon drums, poly or fiberboard drums, and areas of refuse containing discernable zones of unique materials such as apparent polymers or resins. Photographs of each feature are also provided in Appendix 2. The following abbreviated table provides an overview of the features that were sampled:

Feature Identification	Landfill Trench Segment	PID Reading (ppm)	Feature Description
Feature 2	LTR-E-11	0	Cardboard drum (crushed) w/gelatin-like substance inside. No odor. Overpacked for offsite disposal. Feature sample LTR-F02-2.
Feature 7	LTR-E-22	0	A yellowish resin-like material that is present in large chunks (approximately 3 ft by 1.5 ft). Material is intermixed with soil and refuse. Very strong pungent odor present in

Feature Identification	Landfill Trench Segment	PID Reading (ppm)	Feature Description
			material/soil. Feature sample LTR-F07-2.
Feature 13	LTR-W-08	2	Clear to white sticky resin and glue-like material present throughout spoils. Feature sample LTR-F13-2.
Feature 14	LTR-W-10	0	Located at 3 ft bgs, unknown black, sticky, hard resin-like material located throughout entire trench segment. Feature sample LTR-F14-2.
Feature 15	LTR-W-12	1,352	Crushed steel drum encountered at 3 ft bgs. Very strong ether-like odor. Drum contains a purplish, hard, foam material with some pinkish resin-like material. Overpacked for offsite disposal. Feature sample LTR-F15-2.

Although historic information suggested that the landfill was comprised of construction debris, methane (CH₄) and H₂S were identified as potential health and safety considerations because of the geologic setting of the area (swampy meadowmat). Health and safety monitoring was performed throughout the excavation activities for LEL, H₂S, O₂, CO, and PID. During the course of the excavation work, PID readings were observed on the spoils pile and within the excavated trench—the readings ranged from 0.0 ppm to 200 ppm. Elevated readings that would trigger PPE upgrades or continuous perimeter air monitoring action levels, however, were not detected at sustained concentrations in the work or breathing zones.

Strong odors were also present at times, but these odors did not induce elevated PID readings or trigger action levels. Elevated LEL readings were also encountered in areas of the excavation as ground was broken by the excavator bucket. The elevated levels were observed to be short duration episodes that did not sustain concentrations in the work zone or breathing zone, and did not trigger action levels. Overall, the encountered conditions slowed the productivity of the excavation work as conservative and methodical monitoring practices were implemented, but action levels were not triggered throughout the duration of the work. Documentation is included on the individual trench segment logs presented in Appendix 2 for the field monitoring records.

Except for the toe of the landfill, the anthropogenic fill was not observed at the bottom of any of the trench segments because excavation was terminated at the encountered groundwater table (see below regarding level of the groundwater table versus level of anthropogenic fill). Before the toe of the landfill, miscellaneous debris was observed on the ground surface and intermixed with the anthropogenic fill grading to the toe of the landfill. At the toe, the waste materials appear to have been deposited directly over the anthropogenic materials and not in a dump area excavated for the purpose of waste deposition. From the toe, the bottom of the landfilled materials likely slopes downward relative to the anthropogenic level because of settlement caused by the weight of the overlying deposited waste materials.

The water table was encountered in each of the excavation segments prior to excavating through the full thickness of the landfill materials (Figure 3-7). Because the thickness of the landfill materials varied by location, the corresponding depths of the excavations also varied.

Water table was generally encountered at an elevation approximately equivalent to 2 feet below what would be considered ground surface outside the extent of the landfill.

Figure 3-7 presents a conceptual cross section of the landfill.

3.4.2 Results of Landfill Sampling Activities

3.4.2.1 Data Quality

The results from the landfill characterization samples were validated by USEPA, with the following data qualifiers added to the data when the quality assurance/quality control (QA/QC) data indicated a bias:

- U The material was analyzed for but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit.
- J The associated value is an estimated quantity. Used when the data indicated the presence of a component was below the stated reporting limit or when the direction of analytical bias was unknown
- UJ The component was analyzed for but not detected at a level equal to or greater than the reporting limit. Used when QA/QC data indicated a bias in the analytical data but the direction of bias is unknown.
- R Rejected result. Data are of insufficient quality to be deemed acceptable as reported or otherwise qualified.
- N Analyte is presumed present.
- NJ Analyte is presumed present at the estimated numerical value.
- R Value is unusable.

A full discussion of data qualifications is available with the data packages. The data packages are not included in this report because of their volume, but are kept in the project files.

The following samples required dilutions for analyses:

Sampling Location	CLP Sample Designation	Analyses	Dilution
LTR-E-02	B4TL2	SVOCs	4
LTR-E-05	B4TL5	PCBs	4
		Pesticides	4
LTR-W-01	B4TL6	SVOCs	2
LTR-W-02	B4TL7	SVOCs	2
LTR-W-05	B4TM3	Pesticides	10
LTR-W-07	B4TM1	VOCs	4
LTR-W-09	B4TM4	Pesticides	2,000

Review of the data indicated that the quantitation limits (referred to as detection limits throughout the report) were high for some of the analyses and in a few cases, exceeded the NJDEP RDSCC and NRDCSCC criteria used to assess the results.

The analyses and samples where this was noted are listed below; samples which reflect analyses following dilution are bolded.

VOCs—LTR-E-02, LTR-E-04, LTR-W-02, LTR-W-03, LTR-W-05, LTR-W-06, LTR-W-07, LTR-W-08. Except for samples LTR-W-07 and LTR-W-08, this was noted for a few analytes in the samples. While the number of analytes with detection levels higher than the criteria was significantly more in samples LTR-W-07 and LTR-W-08, as discussed below, this does not affect the conclusions that can be made from the data as compounds were detected in these samples above their respective criteria.

SVOCs—LTR-E-01, LTR-E-02, LTR-E-03, LTR-E-04, LTR-E-05, LTR-W-01, LTR-W-02, LTR-W-03, LTR-W-04, LTR-W-05, LTR-W-06, LTR-W-07, LTR-W-08, LTRW09. Except for sample LTR-E-02, this was noted for a few analytes in the samples. While the number of analytes with detection levels higher than the criteria was significantly more in sample LTR-E-02, as discussed below, this does not affect the conclusions that can be made from the data as compounds were detected in this sample above their respective criteria, thus indicating contamination at this location.

Pesticides—LTR-W-05 and LTR-W-09. Sample LTR-W-05 contained only two analytes with detection levels greater than the criteria, while multiple analytes in sample LTR-W-09 contained analytes above criteria. This does not affect the conclusions that can be made from the data because compounds were detected in this sample above their respective criteria, thus indicating contamination at this location.

Possible reasons for these elevated quantitation limits include:

- High concentrations of target compounds, which would have resulted in samples being diluted during the initial analysis
- High concentrations of tentatively identified compounds (TICs), which would have interfered with the quantitation of calibrated, or target, compounds and that, therefore, resulted in the analysis of samples by the medium concentration method
- Sample moisture, which would result in elevated quantitation limits when reporting sample results on a dry-weight basis

For compounds that are reported as not detected at the higher quantitation limit, some uncertainty is associated with the results because the quantitation limits for some of the compounds were higher than the criteria used to evaluate the results. The impacts of the higher quantitation limits in those samples on the overall data evaluation, however, is insignificant, as in all cases, the samples for which this was noted contained compounds that exceeded the criteria, indicating that contamination was present in these samples. Addressing the presence of the compounds found above the criteria during remedial action would also result in addressing compounds that may not have been detected at a sampling location because of their concentrations being lower than the elevated quantitation limits. Of note, resampling is unlikely to resolve this issue. This is because the three possible reasons for the high quantitation limits (high concentrations of target compounds concentrations, interfering compounds, and percent moisture) are all sample dependent, not attributable to poor laboratory practices and, therefore, results are not likely to be different if the locations were to be resampled.

Field QC measures performed during the landfill investigation included collecting duplicate samples, trip blanks, equipment blanks, and extra volume for matrix spike and matrix spike duplicate analyses. In addition, a sample from the fire hydrant which provided water used in decontamination activities was also collected. The results for all water field QC samples are presented in Appendix 6 following the results of the collected groundwater samples. The duplicate sample collected during the landfill investigation is presented following the results for the associated original sample. No contaminants were detected in the equipment and trip blanks suggesting lack of cross contamination between samples.

The analytical data for the TCL and TAL analyses of the landfill features samples were not validated. These data are not planned to be used in estimating the human health and ecological risks associated with the site, but for evaluating the general characteristics of the wastes in the landfill.

The analyses and samples where the detection levels were noted to be higher than the criteria used are listed below; samples which reflect analyses following dilution are bolded.

VOCs—All samples contained at least one analyte with a detection level that exceed the criteria; the sample from Feature 15 (**LTR-F15-2**) contained the highest number of analytes.

SVOCs—Only the sample from Feature 15 (**LTR-F15-2**) contained analytes with detection levels that exceed the criteria.

For the same reasons noted earlier in this section, the elevated detection limits for some of the analytes are not expected to affect the conclusions from the data evaluation because they occurred at locations where other compounds were detected at concentrations above the criteria.

3.4.2.2 Characterization Sampling

Summaries of the analytical data are presented in Tables 3-3 through 3-6. Only samples that contained detectable analyte concentrations are included in these tables. Complete analytical results for all samples can be found in Appendix 2. The tables also compare the detected analyte concentrations to the standards described earlier in this section. Concentrations found to exceed these standards are shaded.

The following represent observations from the data:

- No trends in contamination could be noted from the sampling results.
- All samples contained VOCs. One VOC (benzene) was found to exceed criteria at one location—LTR-W-09.
- All samples contained SVOC, and concentrations in all were found to be above the criteria. The most prevalent compounds found above criteria were benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
- All samples contained pesticides. Four pesticides were found to exceed criteria—heptachlor, heptachlor epoxide and benzene hexachloride (alpha and beta). The concentrations of these compounds (at least one of them) were found to be above criteria in 7 of the 14 samples.
- All samples contained PCBs, and the concentrations in all but one were above criteria.

- All samples contained metals. Two metals were found to exceed criteria—arsenic and lead. The concentrations of these compounds (at least one of them) were found to be above criteria in 12 of the 14 samples.
- The classes of contaminants detected in the landfill samples are consistent with the classes of contaminants found in the surface and subsurface soils during the Phase 1 RI. While concentrations in the landfill may exceed the NJDEP direct contact criteria, the Phase 1 groundwater sampling results did not suggest that these concentrations act as a source to groundwater contamination.

3.4.2.3 Features of Interest

The analytical data are also presented in Tables 3-7 through 3-9. Only samples that contained detectable analyte concentrations are included in these tables. Complete analytical results for all samples can be found in Appendix 2. The tables also compare the detected analyte concentrations to the standards described earlier in this section. Concentrations found to exceed these standards are shaded.

- All samples contained VOCs. Feature 15 was the only sample that contained VOCs above the criteria. The VOCs found above the criteria were benzene, 1,1-dichloroethane, toluene, and 1,1,1-trichloroethane.
- Only the samples from Features 13, 14, and 15 contained SVOCs—Only Feature 15 contained naphthalene above criteria.
- Pesticides and PCBs were not detected in the features.
- All samples contained metals. Two metals were found to exceed criteria—arsenic and lead. The concentrations of these compounds were found to be above criteria only in Feature 14.

3.5 Summary

The following summarizes the results from the landfill investigation and sampling:

- The majority of the landfill contents were observed to consist of municipal-type wastes, with a lesser component of demolition-type debris. Several drums and other features of interest were encountered during the landfill investigation. Because remediation of buried drums and other wastes was not the intent of this investigation, drums and other wastes encountered during the investigation were not removed from the landfill, with the exception of two drums. These drums were suspected to contain materials that could be released to the environment and were, therefore, removed, overpacked and later sampled.
- Ten samples were collected for general characterization of the landfill contents. An additional four samples were biased toward areas where there was staining, odors, or other indication of contamination.
- Twenty-two features of interest were encountered throughout the landfill investigation. These features generally consisted of crushed steel 55-gallon drums, poly or fiberboard drums, and areas of refuse containing discernable zones of unique materials such as apparent polymers or resins. Five of these features, including the two drums noted above, were sampled.

- All samples from the landfill contained VOCs, SVOCs, pesticides, PCBs, and metals. In all samples, there were concentrations for at least one of the classes of compounds that were above the criteria.
- No trends in contamination could be noted from the characterization sampling conducted in the landfill, although, as expected, the data do indicate pervasive contamination throughout the landfill.
- The samples biased toward areas of suspect contamination contained similar contamination to that found in the remaining samples, with the exception of location LTR-W-09. At this location, the concentrations of many compounds in each category were significantly higher than at the remaining locations.
- All 5 features which were sampled contained VOCs and metals. Feature 14 contained metals above criteria and Feature 15 contained VOCs above criteria. Feature 14 is a sample from a resin-like material found in the landfill, and Feature 15 is one of the two overpacked drums.
- Three of the five features sampled contained SVOCs (Features 13, 14, and 15), but concentrations were above criteria only for naphthalene in Feature 15.
- Pesticides and PCBs were not detected in the sampled features.
- The classes of contaminants detected in the landfill samples are consistent with the classes of contaminants found in the surface and subsurface soils during the Phase 1 RI. While concentrations in the landfill may exceed the NJDEP direct contact criteria, the Phase 1 groundwater sampling results did not suggest that these concentrations act as a source to groundwater contamination.

SECTION 4

Laser Induced Fluorescence (LIF) Investigation

Section 4 describes the following:

1. The purpose and scope of the LIF Investigation
2. The implementation of the LIF investigation, including the approach for field delineation and sampling for the purpose of characterizing the mobility and recoverability of the LNAPL
3. The results of the LIF Investigation, including a description of the lateral and vertical extent of LNAPL present at the site based on these results

The results presented in this section are part of a three lines-of-evidence approach used to assess the presence, mobility, and recoverability of LNAPL at the site. The first line of evidence is the LIF investigation. As noted above, the purpose of the LIF investigation is to delineate the extent of the LNAPL at the site. The next section (Section 5) presents the results of the second line of evidence, the LNAPL recoverability pilot test. Section 6 presents the third line of evidence by building upon the results of Sections 4 and 5, and incorporating results of the LNAPL laboratory specialty testing and presenting saturation tests and mobility evaluations to draw conclusions on both the mobility and recoverability of the LNAPL. These multiple lines-of-evidence will be used as a primary basis for technology selection during the evaluation of remedial technologies in the FS.

4.1 Purpose and Scope

The purpose of the LIF investigation was to collect the data necessary to delineate the extent of the LNAPL contamination observed during the Phase 1 RI in the former lagoon area and in the former refinery area at the site.

The specific objectives of the LIF investigation and soil confirmation sampling were to:

- Delineate the lateral and vertical extent of LNAPL, including residual and potentially mobile phases
- Evaluate the degree to which LNAPL contributes to exceedance of the groundwater criteria using SPLP analysis
- Provide the first line of evidence, LIF response as a surrogate for LNAPL saturation, to be used in estimating the extent of potentially mobile LNAPL (these results are discussed in Section 6)
- Provide the first line of evidence, co-located LIF and intact soil core samples for LNAPL saturation analysis, to be used in estimating the order-of-magnitude mobility (i.e., pore fluid velocity) and recoverability of the LNAPL at three diverse locations at the site, including areas of high, medium, and low LIF response (these results are discussed in Section 6)

Each of these objectives was met through completion of the tasks listed below and described in detail in Section 4.2.

- Mobilization of the subcontractor's equipment and set-up at the site
- Performing field delineation activities which included:
 - Onsite delineation of LNAPL using the LIF technology
 - Continuing the LIF delineation activities offsite into the I-280 cloverleaf area
- Performing confirmation sampling activities, which included:
 - Installing conventional soil borings near select LIF locations for visual observations
 - Installing conventional soil borings in order to collect intact core samples for specialty testing of LNAPL and soil properties
 - Collecting soil samples from the borings for SPLP analysis
 - Collecting LNAPL and groundwater pair samples from select monitoring wells for specialty testing of fluid properties
- Demobilization of subcontractors and equipment from the site

4.2 Implementation of LIF Investigation Activities

4.2.1 Field Delineation Approach

On March 3, 2008, Dakota Technologies Incorporated (DTI) mobilized a field technician and specialized LIF equipment to the site in preparation for LIF delineation activities to investigate the presence of LNAPL at the site and offsite. A locally-based direct push technology (DPT) 6610 track-mounted Geoprobe® rig, provided and operated by a New-Jersey-licensed driller from Environmental Probing Investigations (EPI), was integrated with the down-hole LIF screening tool provided by DTI.

LIF is a laser-based technology that utilizes light-energy in the form of a laser to energize and excite hydrocarbon-based chemicals, causing them to fluoresce and emit light. The laser causes hydrocarbons to fluoresce and emit a characteristic spectrum (multiple wavelengths) of light that is detected by the probe tip optical assembly.

LIF technology is introduced into the subsurface by a conventional DPT drill rig outfitted with standard hollow steel drill rods and a specially designed LIF probe point that houses an optical assembly for the laser. A laser generator and control box is housed in a separate support vehicle at ground surface, and laser light is transmitted down the hollow drill rod to the optical assembly probe point through flexible fiber optic cables. A very fast (10 nanosecond) pulse of laser light is emitted from the optical assembly into the adjacent soil. If hydrocarbons are present in the soil, the energy from the laser is absorbed by the contaminants and returned as fluorescent light at a characteristic spectrum of wavelengths. The fluorescent light is captured by the optical assembly in the probe tip and is reflected by mirrors back to the ground surface through the fiber optic cables. A spectrometer and oscilloscope housed on the drill rig evaluate the reflected fluorescent light and transmit a graphical "waveform" describing the characteristics of the fluorescent light to a computer. The intensity of the fluorescence at four different wavelengths is compared against a

pre-calibrated reference emitter (RE), and a strip log of the LIF relative response is produced in units of percent relative to the reference emitter (%RE). The entire process occurs virtually instantly (under 20 nanoseconds), allowing for continuous, real time evaluation of the subsurface at the same rate at which drill rods are advanced.

The LIF tool is employed as an in situ evaluation system that provides real-time, semi-quantitative graphical data. Conventional soil core samples are not collected during routine LIF implementation, but can be collected following the LIF survey from immediately adjacent drilling locations using the DPT drill with conventional tooling.

Initial LIF equipment setup tests and generic calibrations using DTI's proprietary standards were successfully completed and documented by DPI prior to the LIF delineation investigation. A detailed description of DTI's LIF calibration methodology is presented in DTI's *UVOST Investigation Report* included in Appendix 3. The LIF screening tool and optical assembly were subsequently calibrated and checked between each LIF delineation point. All calibration results were within the specified ranges.

Prior to beginning delineation, site verification of the LIF equipment and reference emitter was completed to verify that %RE response is adequate to meet the data needs of the investigation. LNAPL samples were collected from three onsite monitoring wells which historically contained free-phase LNAPL. The three monitoring wells utilized for LIF base-lining were PZ-7, PZ-10, and MW-13S (Table 4-1). A sample of LNAPL from each of the three monitoring wells was placed on the LIF window to gauge relative response of free-phase LNAPL from each sample origin and to observe the characteristic wavelength "signature" of the LNAPL as displayed on a LIF log. All three samples showed adequate RE response results for subsurface LNAPL delineation using the UVOST® system.

In order to correlate in situ LIF %RE responses with soil analytical results from Phase 1 sampling, site specific LIF "calibration" logs were created for baseline understanding of the LIF data (Table 4-1). LIF calibration logs were initially advanced in two known "clean" areas adjacent to soil borings SB-27 and SB-29 where LNAPL saturation was not identified during the Phase 1 RI. Reference data were also collected from locations adjacent to PZ-7, PZ-10, and MW-12S where elevated LNAPL saturations were previously identified. Results of the LIF correlation are presented in Section 4.3.1.

Delineation of the extent of LNAPL at the site was conducted between March 4, 2008, and March 14, 2008. Delineation began within the footprint of the former "oil lake" or lagoon as documented in historic aerial photographs. The 4.3-acre (190,000 square-foot [sq. ft.]) area bounded by the former refinery area/landfill/Wetland Area 4 (MW-3 area) and the I-280 entrance ramp soil berm were the focus of the initial delineation activities which began near existing piezometer PZ-10. Figure 1-2 shows the LIF delineation points, boring identification names, and the boundaries of the former oil lagoon area.

Delineation probing initially commenced on a grid system with probing at 50-foot center points. Actual probe spacing, location, terminal depths, and delineation were then adjusted in accordance with evaluation of real time results, field conditions, and progress of field activities using a dynamic and adaptive process where daily LIF logs were analyzed by the project team from both investigation, as well as remediation, data needs standpoints.

Delineation of the LNAPL source area progressed to the east of the site in the cloverleaf area of the entrance ramp for I-280. Delineation was completed in the grassy areas of the cloverleaf away from the paved roadway areas. Three areas of the I-280 cloverleaf

exchange were targeted to investigate the presence of LNAPL based on the apparent maximum extent of the former oil lagoon area, as shown on historical aerial photographs.

Throughout the investigation area, each LIF boring was advanced to a depth of at least 2 feet below the LNAPL as determined by the LIF log results. All borings were terminated prior to contacting the peat layer (as determined by correlation with nearby Phase 1 soil boring logs) to avoid compromising this stratigraphic unit. The average terminal depth of onsite LIF borings was 11.2 feet, and offsite borings averaged a depth of 11.7 feet. The delineation probing continued until an area of "low" response was encountered (as compared to the baseline responses), indicating that delineation had been achieved. A total of 1,212 linear feet of LIF data were collected. Each boring location was abandoned in accordance with NJDEP requirements.

During the LIF investigation, data were collected at 90 LIF delineation points. Because of drilling refusal encountered at some LIF locations, multiple offsets were required to identify a location clear for drilling. In these instances, several LIF logs were created and boring offsets are distinguished by alphabetical depiction (e.g., LIF-007, LIF-007B).

LIF data were continuously logged and documented by DTI at each LIF delineation point. Each LIF log shows a graphical representation of the total fluorescence signal relative to the %RE, and is represented as a color-coded, scaled graphical log. The vertical axis of the graph corresponds to depth bgs, and the horizontal axis quantifies the relative fluorescence of contamination observed in the soil, as referenced to the standardized source. The data are presented as %RE. Examples of LIF logs demonstrating low, medium, and high response are provided in Figures 4-1, 4-2, and 4-3, respectively. All of the LIF logs collected during the Phase 2 RI are included in Appendix 3.

At the conclusion of LIF delineation, spatial information of interest was recorded by CH2M HILL at each LIF delineation point and confirmatory soil boring location using a Trimble GeoXT™ with GeoBeacon™ to an accuracy of less than 1 meter. The spatial information collected at each LIF delineation point and Phase 2 soil boring is presented in Appendix 3.

4.2.2 Confirmation Sampling Methodology

A limited conventional soil boring program was implemented in conjunction with the LIF investigation to log soil cores and ground truth the observed LIF responses against field observations, and collect soil cores and LNAPL and groundwater samples for specialty petrochemical laboratory testing (Table 4-1). The objective was to gather data to evaluate the LNAPL in terms of its potential mobility/recoverability and leachability of its contaminants to groundwater. The limited soil boring program consisted of installing conventional soil borings near select LIF locations for visual observations, installing conventional soil borings in order to collect intact core samples for specialty testing, collecting soil samples from the borings for SPLP analysis, and collecting LNAPL and groundwater pair samples from select monitoring wells for specialty testing. These are described below.

Conventional Soil Borings

Soil core samples were collected adjacent to three LIF delineation points using the direct push drill rig and conventional macro-core-type samplers. The coring locations were based on LIF results in order to visually correlate low-, medium-, and high-response LIF logs. A soil boring log, LIF-17-00-13-2, was created adjacent to LIF-017 to visually correlate an area of low %RE response (maximum LIF response was 16.5 %RE). Soil boring log

LIF-34-00-12-2 was collected adjacent to LIF-034 to correlate an area of medium response (maximum LIF response was 99.3 %RE), and LIF-012-00-13-2 was from an area of high %RE response (maximum LIF response was 238.2 %RE) adjacent to LIF delineation point LIF-012. Logs are provided in Appendix 3.

All three soil cores were visually observed for indications of LNAPL, screened for VOCs with a PID, and the geology logged for correlation with the LIF profiles. Soil samples were not collected for conventional environmental analysis because this sampling was already performed during the Phase I Investigation.

Intact Core Sampling

Intact soil core samples were collected and analyzed from four locations adjacent to LIF delineation points of high (two depth intervals), medium, and low %RE response. The results were used to help estimate the potential in situ mobility and recoverability of the LNAPL in conjunction with the LNAPL recovery tests. The sampling procedures and results are discussed in detail in Section 6 of this report.

SPLP Sampling

Four soil grab samples were collected from core samples for analysis for VOCs and SVOCs following the SPLP. SPLP analysis is used as a surrogate to simulate rainfall infiltration or groundwater contact with LNAPL that is submerged. The analysis was performed by Chemtech Laboratory.

Each sample was collected adjacent to existing wells/piezometers at depths equivalent to historic soil VOC samples from the Phase 1 investigation. After evaluating the Phase 1 data and LIF logs, the following SPLP sampling locations were selected:

Phase 2 SPLP Sample	Depth (feet bgs)	Phase 1 Soil Boring Correlation
SB-39	5–6	MW-13D
SB-40	7–8	MW-14S
SB-41	15–17	PZ-2
SB-42	5–6	PZ-10

SPLP soil samples were collected using dedicated acetate MacroCore™ sleeves. Each VOC and SVOC soil sample was collected at a pre-determined interval based on peak %RE responses observed from adjacent LIF data. SPLP samples were collected using dedicated scoops and preserved, packaged, and shipped to the laboratory in accordance with the Phase 2 UFP-QAPP.

4.2.3 Results of the LIF Delineation

The UVOST® technology was utilized during the LIF investigation to delineate the extent and distribution of LNAPL at the site. By combining multiple lines of evidence from base lining of the LIF technology to site LNAPL samples, correlation of LIF data with Phase 1 analytical data, observations from confirmatory soil borings, and specialized petroanalysis from LNAPL-containing soil cores, a representative range of %RE response was identified that potentially corresponds to areas of LNAPL that are potentially mobile/recoverable and/or leaching contamination to groundwater. These correlations were then used to

delineate the lateral and vertical extent of LNAPL at the site that is adversely affecting groundwater quality. Sections 5 and 6 of this TM build on these results by reviewing the potential mobility and recoverability of the LNAPL.

Evaluating LIF Log Data

A number of interpretations of subsurface conditions can be drawn from the semi-quantitative LIF data. The amplitude of a response spike on the fluorescence axis corresponds to the relative concentration of LNAPL constituents in the soil and the fluorescence response by those constituents. The UVOST® system is also able to roughly compare the relative strengths of a few key wavelengths of fluorescent light emitted by the contaminant and qualitatively distinguish between variations in the LNAPL composition. These variations in fluorescence are displayed as different colors in the graphical output. Because the fluorescence is calibrated to a reference LNAPL standard sample, the relative differences in fluorescence response observed in each profile is comparable between boring locations. Hence, whenever the blue, yellow, or orange responses are noted on a boring log, they can be interpreted as having similar LNAPL compositions as other boring logs with like colors and %RE responses across the site. Alternatively, differing color and %RE responses allow for the relative identification of different LNAPL source areas or weathered LNAPL within the same site. The actual concentration, chemical components, and degree of weathering of the LNAPL cannot be specified with this technology, and necessitate confirmation sampling to verify them.

All of the LNAPL baseline samples collected from wells MW-3, PZ-10, and PZ-7 showed adequate response with the UVOST® LIF instrument. LIF baseline results, displayed in the LNAPL baseline LIF log (Appendix 3), show some product variability between the samples from MW-13S and PZ-10/PZ-7. MW-13S showed strongest fluorescence in the 400 pV range, thus color-coding more in the green range. PZ-10 and PZ-7 each showed strongest fluorescence in the 450 pV range (orange) which displayed yellow on the logs. This variation could be because of different product types, weathering effects, or mixing of products (e.g., diesel fuel and oil).

As a rule, the multiple lines of evidence of data indicate the following:

- A fluorescence response of less than **10 %RE** is considered “unaffected soil” absent of LNAPL, such as at borings LIF-CAL-SB-27 and LIF-CAL-SB-29 taken at areas defined as clean during the Phase 1 RI.
- A response of **less than 15 %RE** is indicative of residual LNAPL, as shown by LIF logs adjacent to MWs and PZs containing no in-well LNAPL.
- A response of **less than 40 %RE**, as depicted on log LIF-001, appears to be LNAPL that is not leaching to groundwater.
- A response of more than **40 %RE** with a green UVOST® graphical fingerprint appears to indicate the presence of LNAPL that may leach to groundwater.

From the 90 LIF profiles conducted at the site, 15 profiles indicated little to no LNAPL constituents (< 10 %RE), 3 profiles indicated the presence of residual LNAPL (< 15 %RE), 25 profiles indicated the presence of LNAPL that is not leaching to groundwater (< 40 %RE), and 47 profiles indicated the potential presence of LNAPL that may leach to groundwater (> 40 %RE). Of the 47 profiles with %RE response greater than 40 which indicates the potential presence of LNAPL that may leach to groundwater, 24 profiles have a green fingerprint that appears indicative of less weathered and, therefore, leachable LNAPL, and

23 profiles have a yellow to orange profile that appears indicative of weathered LNAPL material that is no longer leachable.

Cross Sections and 3-D Graphics

The raw data from the LIF logs were evaluated using an accurate, geostatistically defensible process called Kriging to create 3-dimensional (3-D) graphics to illustrate the lateral and vertical distribution of LNAPL. The MVS software package by C-Tech (<http://www.ctech.com>) was used for the Kriging and to create the graphics. It should be noted that this graphics package was not fully validated as a computer “model” of the contamination, but the visualizations created provide a valuable tool for understanding overall site conditions.

Figures 4-4 through 4-10a provide an overview of the distribution of LNAPL contamination at the site. The figures show 2-dimensional (2-D) and 3-D views of LNAPL occurrence in the subsurface based on the numerical MVS calculations. The three major features illustrated in the graphics include: 1) LIF boring locations, 2) the 3-dimensional surface of the LNAPL at specified LIF %RE values, and 3) the depth of geologic units and the water table. An aerial photo of the ground surface, several labeled LIF boring locations, and other labeled landmarks provide location references. The vertical scale of the graphics is exaggerated ten times to compensate for the relatively shallow vertical sequence (approximately 20 feet) compared to the long lateral distances of the study area (approximately 750 to 1,100 feet). The vertical sequence is also shown in “exploded layers” view, separating the distinct layers of geology with a blank space so the distribution of LNAPL in the various lithologic layers can be shown clearly.

The LIF boring locations are illustrated by vertical tubes that are color-coded based on the LIF %RE response. Lower %RE response values are represented by green to yellow shading and higher %RE responses are shown with orange to red shading. Because these are 3-D views (or shells) of the plume, higher %RE values that occur toward the center of the plume are typically obscured by the outer plume surface, similar to the layers of an onion.

The process of Kriging the LIF data involved interpolating and extrapolating the equivalent %RE value for the LNAPL throughout the study area. In the Kriging process, a statistical measure of the uncertainty in the data are created. This uncertainty, which is inherent in our understanding of natural systems, is depicted on a second version of each graphics figure notated with an “a” in the figure number and titled “Data Confidence Evaluation...” (e.g., Figure 4-5 presents a cross-sectional view and Figure 4-5a presents the same view depicting the confidence evaluation). These data confidence figures are also color coded such that the color indicates the confidence that the location of the true %RE surface is known. The confidence scale for these graphics is between 70 to 100% and is based on a +/- two-times factor for the %RE iso-surface value (meaning the true value is between one-half and two-times the Kriged value). More simply stated, darker blue colors indicate locations where confidence is higher and we have a better understanding of the plume (up to 100% confidence at each LIF boring location), and lighter green colors indicate locations where confidence is lower (approximately 70% at the edges of the graphics) and we have a poorer understanding of the plume. Based on the large number of LIF data points that were collected across the study area, the overall confidence level in the data Kriging is very high for these graphics (generally 90% to 100% confidence), with the uncertainty entering at the edges of the study area.

The first series of figures present 2-D cross-sectional views representing a "slice" through the subsurface, showing the interior of the LNAPL plume the way a slice of bread shows the interior of the loaf. Figure 4-4 is a plan view of the site showing the layout of the cross-sectional views of the LNAPL source area. Cross-section A-A' shown in Figure 4-5 is a south-to-north transect on the Diamond Head property through the former oil lagoon area and the former refinery process area. The color-coding in this figure represents the %RE response in the LIF data and shows all data greater than 10 %RE (the cut-off value below which was determined to represent areas unaffected by LNAPL). The distribution of the LNAPL can be seen in this figure occurring at and below the water table (January 29, 2008, measurement) and extending into the saturated zone well below the water table in some areas. Correspondingly, Figure 4-5a shows the data confidence evaluation for cross section A-A' and the color-coding in this figure represents the confidence level in the data. Note the high confidence level represented by dark blue colors throughout the figure, with uncertainty entering only at the edges of the study area. The LIF boring locations shown on this data evaluation figure include color-coding of the actual %RE data for reference.

Cross section B-B' shown in Figure 4-6 is a southwest-to-northeast transect beginning in the former oil lagoon area of the Diamond Head property and continuing offsite through the I-280 cloverleaf area and the historic extent of the oil lagoon as seen in historic aerial photographs. The color-coding in this figure also represents the %RE response in the LIF data and shows all data greater than 10 %RE. The distribution of LNAPL is comparable to that observed in the other figure. Correspondingly, Figure 4-6a shows the data confidence evaluation for cross section B-B', and the color-coding in this figure represents the confidence level in the data.

As shown in both cross sections, the LNAPL occurs predominantly below the water table depth measured at the time of the LIF investigation. This phenomenon is being reported more regularly in the literature, as LNAPL sites are being evaluated more comprehensively. In addition, while all the product at the site was characterized as "LNAPL"-type product through the Phase 1 RI sampling program, separate layers of LNAPL are observed at various depths across the site, often with distinct stratification at the same boring location. As shown by the %RE LIF profiles, the highest concentrations of LNAPL (e.g., red shaded colors in the cross sections) are predominantly located near the water table within the fill layer, but are also present within silt/clay in deeper portions of the LNAPL plume.

The second series of figures present views of the plume in the subsurface and show a 3-D view of the LNAPL mass at the specified "shell" concentrations of %RE. These views show the *outer* shell of the plume as if layers of an onion were peeled away for each new view. Figure 4-7 is a plan-view graphic showing the lateral extent of LNAPL based on LIF data greater than 10 %RE. Because this is a 3-D view of the outside of the 10% shell, the entire area receives the same (yellow) color-coding on the graphic. This graphic represents the size of the total area that is interpreted as being affected by LNAPL. The corresponding Figure 4-7a shows the data confidence evaluation for this figure and the color-coding represents the confidence level in the data. Again, note the high confidence level in the data until the edges of the study area are reached.

Figure 4-8 is an oblique view of the same 10 %RE graphic shown in the previous figure. The oblique view is similar to a cross section except the *exterior* of the plume shell is shown to illustrate the extent of the plume. Color-coding in this figure again represents the 10 %RE shell (yellow color-coding), except along the edge of the graphic where the plume is cut off by the edge of the study area and the interior concentrations of the plume are seen (red color-coding). Note the vertical thickness of the LNAPL present in the subsurface. The

corresponding Figure 4-8a shows the data confidence evaluation for this figure, and the color-coding represents the confidence level in the data.

The portion of the LNAPL plume with LIF response greater than 40 %RE is shown in the next series of graphics. This 40 %RE area (equivalent to the inner layers of the LNAPL "onion") is interpreted to represent the portion of the LNAPL mass that may leach to groundwater. Figure 4-9 is a plan-view graphic showing the lateral extent of LNAPL based on LIF data greater than 40 %RE. Compare the size and location of this 40 %RE shell to the 10 %RE shell shown in Figure 4-7. The difference in LNAPL area between the graphics represents the volume of the plume that is interpreted as not contributing to the degradation of groundwater quality. The corresponding data quality evaluation for Figure 4-9 is provided in Figure 4-9a.

An oblique view of the 40 %RE graphic is shown in Figure 4-10. Color-coding of the exterior of the plume shell in this figure again represents the 40 %RE response (orange shading) until the edge of the study area is encountered and the interior of the plume is seen in red color-coding. The vertical thickness of the LNAPL is demonstrated in this graphic along with the presence of discrete pockets of LNAPL at different depth horizons. The data quality evaluation corresponding with this figure is shown in Figure 4-10a

These graphics show the lateral distribution of LNAPL is concentrated on the Diamond Head property and in limited portions of the grassy clover leaf sections of I-280. The stratification in the vertical distribution of LNAPL is also seen in these 3-D images.

The numerical nature of the software package permits the calculation of useful data. The following table summarizes the estimated volumes of soil that contain LNAPL for each subsurface layer of geology and at the described %RE responses (see Figures 4-5 and 4-6 for distribution of the layers):

Soil Volumes (cu yd) Containing LNAPL at LIF %RE Values

Subsurface Layer	> 10 %RE	> 40 %RE	> 60 %RE
Fill	40,219	3,709	1,490
Clay Layer 1	375	0	0
Silt	968	47	14
Sand	709	27	11
Clay Layer 2	12,372	494	194
Peat	120	0	--
All Layers Combined	54,764	4,276	1,706

Further evaluation of the distribution of these soil volumes shows that as the %RE increases, the volume of impacted soil volume decreases exponentially. For example, the total volume of affected soil at the > 10 %RE threshold is 54,764 cubic yards (cu yd), but the volume of affected soil at the > 40% threshold decreases exponentially down to 4,276 cy yd. Also note that fill comprises 75% to 87% of the total impacted soil volume. Of the remaining volume, up to 23% of the impacted soil occurs in the deeper clay layer. These volumes and distribution will be important factors while evaluating remediation options during a Feasibility Study.

Additional Observations

Limitations to the LIF delineation of LNAPL primarily correspond with inaccessibility to areas of the site where LIF probing could not be performed. While access to the site was greatly increased by the site preparation and the constructed temporary roads, areas of the site remained where standing water and soft ground prevented access with the drill rig.

The LIF profiles from across the site can generally be divided into four characteristic profile types distinguished by the depth and persistence of the contamination that is observed. An example of the classic LNAPL at the water table profile is seen in Figure 4-11 of LIF-032 where a concentrated occurrence of contamination is observed at the water table interface (approximately 2 feet bgs). The second characteristic profile is a variation of this as shown in Figure 4-12 of LIF-012 where the shallow contamination occurs at the water table, and also exhibits an extended smear zone where contamination is continuously present to approximately 8 feet bgs. The third characteristic profile is seen in Figure 4-13 of LIF-034 where the zone of higher contamination begins below the water table and continues as an extended smear zone within the saturated soils down to a depth of 9.5 feet bgs. The final characteristic profile is demonstrated in Figure 4-14 of LIF-CAL-PZ7, where a shallow occurrence of contamination may or may not be observed at or below the water table, and then a discrete zone of deeper contamination occurs at depths of 10 to 15 feet bgs. From these characteristic LIF profiles, the occurrence of LNAPL contamination at the site can be separated into two depth intervals as demonstrated in the 3-D graphics: 1) occurring at the water table and sometimes with an extended smear zone into the shallow saturated fill material/soils up to 10 feet bgs, and 2) occurring as a distinct deeper interval at depths of 10 to 15 feet bgs within silty/clayey soils.

A variation in the LIF log color-coding is also observed between the detected LNAPL contamination at different depth intervals. Based on the cumulative wavelength of fluorescent light emitted by the contamination, the LIF responses in the shallow zone are generally color-coded in the green range, while the LIF responses in the deeper zones are generally color-coded in the yellow range. This indicates a qualitative differentiation in the type of contamination present in the subsurface. The differentiation may be because of the presence of different product types, the degree of weathering of the same product type, and/or mixing of different product types. The low %RE responses in the orange color-coding range observed toward the bottom of the LIF logs is likely indicative of background interference by organic materials in the peat soil that was encountered.

4.2.4 Results of Confirmation Sampling

Conventional Boring Log Comparison

The effectiveness of the LIF tool was qualitatively confirmed through the installation and comparison of conventional soil borings immediately adjacent to areas designated at low (LIF-017), medium (LIF-034), and high (LIF-012) %RE response (soil boring logs presented in Appendix 3). The comparison of soil boring logs and LIF logs showed the concurrent presence of petroleum odors, elevated PID readings, visual LNAPL staining in corresponding intervals of low, medium, and high %RE response. The comparison confirmed that the LIF logs accurately characterized soil conditions ranging from unaffected "clean" soil to zones containing free-phase LNAPL.

In some cases, LIF responded to naturally fluorescent minerals and organic matter. Most often, this response shows a very different wavelength signature and relatively low response compared to the site LNAPL. After retrieving the soil core at boring LIF-017, a section of soil

with no indication of the presence of LNAPL was collected from the 7.0- to 7.5-foot interval and placed directly on the LIF sensor. As shown in log LIF-17-SB 7-7.5 (Appendix 3), the waveform is dominated by narrow peaks within the 450 pV range (orange color coding). This LIF signature is unlike the signatures produced by baseline samples of the site LNAPL. Relatively low %RE responses composed of the 450 pV waveforms are present at various intervals throughout the site-wide LIF logs, which may be a result of interference caused by naturally-occurring organic material (i.e., peat) in the soil.

SPLP Results

SPLP results were used to evaluate the leachability of LNAPL-containing soil and identify areas containing LNAPL that may be acting as a source to groundwater. A summary of the detected compounds is presented in Table 4-2, and the full results are provided in Appendix 3. The corresponding VOC and SVOC analytical data from co-located Phase 1 RI samples are presented in Tables 4-3 and 4-4, respectively.

The SPLP test simulates what may be leached from the LNAPL-containing soil to the groundwater because of water infiltration (e.g., rainwater) or submerged in continuous contact with groundwater. In the absence of directly applicable criteria or standards, the SPLP results were compared to the New Jersey Class IIA groundwater criteria. These criteria apply to all groundwater in New Jersey. Three compounds were detected in the SPLP extract above the method detection levels—benzene, cresol-o, and cresol-p. A New Jersey Class IIA groundwater standard was available only for benzene. The concentration of benzene in the SPLP extract from a single sample from SB-39 adjacent to MW-13S (12 µg/L) exceeded the standard (1 µg/L), indicating that soils in this area may be contributing to groundwater contamination (at least for benzene) exceeding the New Jersey groundwater quality standards.

Review of the co-located data sets as presented in Table 4-5 provides an illustration of the significance of the SPLP results. The only SPLP results indicating the potential for leaching as a source of contamination to groundwater were at boring SB-39. The LIF results (LIF-CAL-MW13S) from the corresponding depth interval presented a 41 %RE and a green color coding “fingerprint”. The other SPLP data (Table 4-2) indicated that the LNAPL constituents were not likely to leach to groundwater. The LIF data corresponding to the other SPLP samples (Table 4-5) indicated %RE responses of 15% and 28% (no LIF data available at this depth interval in LIF-001 corresponding with SB-41) and green/yellow fingerprint color-coding. These data indicate that a LIF response in the 40%RE range corresponds to a potential source for leaching to groundwater. The solid green hue in the LIF cool-coding fingerprint may also indicate a more leachable material compared to the yellow-, red-, or orange-range fingerprints. This may also correlate with an indication of the relative degree of LNAPL weathering where the green fingerprint is less weathered (and, therefore, available to leach), and the remaining color-coding spectrum increases in weathering (and is, therefore, less prone to leaching).

Of note, the SPLP samples for VOC analyses needed to be diluted five times, as a result of which the quantitation limits (also referred to as detection limits in the report) were high for some of compounds and, for a few, exceeded the New Jersey Class IIA groundwater quality criteria used to evaluate the SPLP result for the compound. The compounds for which this was noted are listed below.

Compound	New Jersey Groundwater Quality Standard	Lowest SPLP DL Achieved
1,1-Dichloroethene	2	3.4
Benzene*	1	1.8
Trichloroethene	1	1.7
Tetrachloroethene	1	4.8

**Three of the four samples analyzed had detection levels above the New Jersey Class II A groundwater quality criteria. Concentrations are in µg/L.*

Possible reasons for these elevated quantitation limits include:

- High concentrations of target compounds, which would have resulted in samples being diluted during the initial analysis
- High concentrations of TICs, which would have interfered with the quantitation of calibrated, or target, compounds and that, therefore, resulted in higher detection levels

For the above compounds, there is, therefore, uncertainty as to whether they are present in the SPLP extract at concentrations exceeding the groundwater quality standard, but below the detection limit. The significant exceedance noted for benzene in one of the samples (12 µg/L compared to the 1 µg/L criteria) indicates that this potential exists. Of note, addressing the presence of the compounds found above the criteria during remedial action would also result in addressing compounds that may not have been detected at a sampling location because of their concentrations being lower than the elevated quantitation limits. It should also be noted that resampling is unlikely to resolve this issue. This is because the possible reasons for the high quantitation limits are all sample dependent, not attributable to poor laboratory practices and, therefore, results are not likely to be different if the locations were to be resampled. The analytical data for the SPLP samples were not validated since these data are not planned to be used in estimating the human health and ecological risks associated with the site.

Additional Observations

A difference in the mean grain size of soils is observed corresponding with the depth intervals where LNAPL contamination is observed. The grain size analysis data presented in Appendix 5 demonstrates that the shallow interval consists predominantly of medium sand-containing fill material, while the deeper LNAPL interval consists of fine sand and silt. Additionally, soil core samples from the deep intervals used for pore fluid saturation analysis by PTS Laboratories were observed to disintegrate and not retain competency as a soil core when dried. The laboratory described this unusual occurrence as being potentially indicative of the "soil" actually consisting of anthropogenic ash-waste sludge (that may have a high holding capacity for LNAPL) as opposed to actual soil. The field geologist's soil boring logs describing these saturated soils, however, generally classify the soil as an olive gray to black, silty clay that has high plasticity and is soft to moderately stiff, with distinct organic plant fragments and a moderate to strong petroleum hydrocarbon odor, and occasional LNAPL sheen with PID readings ranging from 5 ppm to 180 ppm.

4.3 Summary

The following summarizes the results from the LIF investigation:

- The UVOST® technology utilized during the LIF investigation was observed to be an effective and efficient tool for real-time characterization and delineation of LNAPL.
- As a rule, a fluorescence response of less than 10 %RE is considered “unaffected soil” absent of LNAPL, such as at borings LIF-CAL-SB-27 and -29, taken at areas defined as clean during the Phase 1 RI. A response of **less than 15%** is indicative of residual LNAPL as shown by LIF logs adjacent to MWs and PZs containing no in-well LNAPL. A response of **less than 40 %RE**, as depicted on log LIF-001, appears to be LNAPL that is not leaching to groundwater. A response of more than 40 %RE with a green UVOST® graphical fingerprint appears to indicate the presence of LNAPL that may leach to groundwater.
- The comparison of soil boring logs and LIF logs showed the concurrent presence of petroleum odors, elevated PID readings, visual LNAPL staining in corresponding intervals of low, medium, and high %RE response. The comparison confirmed the LIF logs accurately characterized soil conditions ranging from unaffected “clean” soil to zones containing high concentrations of LNAPL.
- Three compounds were detected in the SPLP extract—benzene, cresol-o, and cresol-p. The SPLP extract concentrations were compared to the New Jersey Class IIA groundwater quality criteria. The concentration of benzene in the SPLP extract from a single sample (12 µg/L) exceeded the criteria (1 µg/L), indicating that LNAPL-containing soils in this area of MW-13S may be contributing to groundwater contamination (at least for benzene). Of note is that the detection limits for several of the VOCs (including benzene in three of the four samples analyzed) were slightly above the Class IIA criteria. It is, therefore, possible that other VOCs are present in the SPLP extract at concentrations above the criteria, but could not be detected. The significant exceedance noted for benzene in one of the samples indicates that this potential exceeds—that is, that the LNAPL may be resulting in concentrations in groundwater above the New Jersey Class IIA groundwater quality criteria. The results for the elevated detection levels for the VOCs are believed to be because of sample characteristics and, therefore, resampling is not expected to result in additional information.
- A LIF response in the 40 %RE range corresponds to a potential source for leaching to groundwater. The solid green hue in the LIF color-coding fingerprint may also indicate a more leachable material compared to the yellow, red, or orange range fingerprints. This may also correlate with an indication of the relative degree of LNAPL weathering where the green fingerprint is less weathered (and, therefore, available to leach) and the remaining color-coding spectrum increases in weathering (and is, therefore, less prone to leaching).
- Limitations to the LIF delineation of LNAPL primarily correspond with inaccessibility to areas of the site where LIF probing could not be performed.
- The LIF profiles from across the site can generally be divided into four characteristic profile types distinguished by the depth and persistence of the observed contamination. From these characteristic LIF profiles, the occurrence of LNAPL contamination at the site can be separated into two depth intervals, as demonstrated in the 3-D graphics:
 - 1) occurring at the water table and sometimes with an extended smear zone into the

saturated fill-containing material/soil up to 9.5 feet bgs, and 2) occurring as a distinct deeper interval at depths of 10 to 15 feet bgs within silty/clayey soils.

- A variation in the LIF log color-coding is also observed between the detected contamination at different depth intervals. The LIF responses in the shallow zone are generally color-coded in the green range, while the LIF responses in the deeper zones are generally color-coded in the yellow range. The differentiation may be because of the presence of different product types, the degree of weathering of the same product type, or mixing of different product types. The low %RE responses in the orange color-coding range observed toward the bottom of the LIF logs are considered indicative of background interference by organic materials in the soil.
- Separate layers of LNAPL are observed at different depths across the site, often with distinct stratification at the same boring location. As shown by the %RE LIF profiles, the highest concentrations of LNAPL (e.g., red-shaded colors in the cross sections) are predominantly located near the water table within the fill layer, but are also present within silty/clay in deeper portions of the LNAPL plume.

SECTION 5

Pilot Test—LNAPL Recovery Test

Section 5 describes the following:

1. The purpose and scope of the LNAPL pilot recovery test
2. Implementation of the LNAPL pilot recovery test, including the approach for installation of temporary piezometers and collection of water level and LNAPL thickness measurements before and after the recovery test
3. LNAPL sampling for the purpose of assessing its chemical composition and characterizing it for disposal
4. The results of the LNAPL pilot recovery test

5.1 Purpose and Scope

The purpose of the LNAPL recovery pilot test was to collect the data necessary to provide the second line of evidence in assessing the mobility and the recoverability of the LNAPL observed during the Phase 1 RI in the former lagoon area.

The pilot test included pumping LNAPL from wells and observing the rate of LNAPL recovery, rate of water and LNAPL level change in adjacent monitoring locations, and the rate of LNAPL accumulation (recharge) in the pumped well after cessation of LNAPL pumping. Temporary piezometers were also installed to monitor the recovery pilot test and to evaluate the mobility of the LNAPL. Finally, the recovered product was sampled to assess its chemical composition and to characterize it for disposal. Waste characterization and disposal are discussed in the section on waste management.

Based on the results of the test, the LNAPL hydraulic characteristics and velocity for its migration were estimated. These characteristics then served as the basis for describing the mobility and recoverability of the LNAPL.

5.2 Implementation LNAPL Recovery Test

5.2.1 Installation of Temporary Piezometers

To collect the necessary data during the pilot test, five 1-inch-diameter temporary piezometers were installed between March 20 and March 21, 2008. Three of the temporary piezometers (PZ-18, PZ-19, PZ-20) were installed to evaluate the ability of LNAPL to seep under ambient gradients. The locations for these temporary piezometers were selected by evaluating LIF logs and selecting three locations based on areas of low, medium, and high %RE response. The piezometers were used to evaluate the mobility of the LNAPL detected on the LIF logs by observing if LNAPL would accumulate in the piezometers, which were monitoring each of the three LIF %RE response ranges. Two other piezometers, PZ-21 and PZ-22, were installed in close proximity to PZ-7 to assist in the LNAPL thickness measurements and drawdown observations during the recovery test. The results of this pilot testing

were used in conjunction with the data collected during the LIF investigation (see Section 4) to help define the extent of mobile and recoverable LNAPL as discussed in Section 5.3.

The five temporary piezometers were installed at the following locations, as shown in Figure 1-2:

Temporary Piezometer Identification	Correlating LIF Delineation Point	LIF Response	Screened Interval (feet bgs)
PZ-18	LIF-012	High	1–10
PZ-19	LIF-040	Low	1–11
PZ-20	LIF-032	Medium	1–11
PZ-21	LIF-CAL-PZ-07	High	1–15
PZ-22	LIF-CAL-PZ-07	High	1–15

All of the piezometers were installed by EPI using a truck-mounted Geoprobe® 5410 equipped with DPT to install a 2-inch-diameter borehole. The temporary piezometers were constructed using 1-inch-diameter, Schedule 40 polyvinyl chloride (PVC) with 0.01-inch (10-slot) slotted screen spanning the entire thickness of the LNAPL smear zone as projected from corresponding LIF logs. Certified clean silica sand was installed around the entire length of screen to a depth of 6 inches bgs (clean certification provided in Appendix 4). A bentonite seal was added from the top of the gravel pack to ground surface. Well construction diagrams are provided in Appendix 4. All temporary piezometers were allowed to equilibrate for 24 hours to allow the LNAPL thickness to stabilize. Upon completion of LNAPL recovery testing, the piezometers were abandoned in accordance with NJDEP regulations.

Spatial information was recorded by CH2M HILL at each of the five temporary piezometers using a Trimble GeoXT™ with GeoBeacon™ to record GPS coordinates to an accuracy of less than 1 meter. The spatial information collected is presented in Appendix 4.

CH2M HILL utilized transit level and stadia rod techniques on March 26, 2008, to measure elevations for each of the five temporary piezometers. Elevation data collected at MW-12S during the Phase 1 RI was used as a benchmark while using the transit and stadia rod survey technique. Survey data were collected to an accuracy of 0.01 foot at the top of each piezometer casing (PVC well riser) and the ground surface on the north side of each piezometer. The collected elevation data are included in Appendix 4.

5.2.2 Water Level and LNAPL Thickness Measurements

Two sets of sitewide synoptic measurements were performed to gauge water level and LNAPL thickness at the site (Appendix 4). The first event was performed on January 29, 2008, at the beginning of the Phase 2 Investigation field activities prior to installation of the temporary piezometers. This event served as a baseline for the Phase 2 RI and evaluated site conditions since the previous measurements collected during the Phase 1 RI in August 2003. The second synoptic gauging event was performed on April 14, 2008, immediately before the start of the LNAPL recovery tests. The measurements were collected manually using electronic tape oil/water interface probes by two staff working simultaneously. Because of the high viscosity of the LNAPL, thickness measurements were time consuming

because the product coated the probe, and multiple measurements were required to demonstrate reproducibility. Subsequent LNAPL thickness measurements were also recorded during the LNAPL recovery test from select wells, piezometers, and temporary piezometers and are recorded on field logs, but are not summarized here because the measurements did not constitute a complete synoptic measuring event.

Groundwater potentiometric surface maps for the shallow overburden interval above the peat layer for January and April are presented in Figures 5-1 and 5-2. The corresponding LNAPL thickness measurements for January and April are presented in Figures 5-3 and 5-4. Note that a correction factor was applied to the groundwater potentiometric surface elevations to compensate for the density of LNAPL depressing the water table. The following correction factor was used where the measured specific gravity of the product at the site is 0.89, the well casing elevation is relative to mean sea level, and the static depth to water in the well is relative to the top of inner well casing:

Well Casing Elevation - (Static Depth to Water - [LNAPL Thickness x LNAPL Specific Gravity])

(Source: NJDEP Field Sampling Procedures Manual, Section 6.9.8.4, August 2005)

5.2.3 LNAPL Recovery Test

In order to evaluate the subsurface conductivities and transmissivities as they relate to the mobility and recoverability of the LNAPL, an LNAPL recoverability or bail down test was performed to assist in the evaluation of fluid recovery technologies that may be used to remove the practicably recoverable LNAPL.

Bail Down Pre-Test

An LNAPL bail down pre-test was completed on January 30, 2008, at the onset of the Phase 2 RI in order to evaluate specific equipment needs and to determine the suitability of the existing piezometer and monitoring well network for an LNAPL pilot test study.

An assessment of well MW-3 and the surrounding existing network of piezometers revealed that piezometers PZ-7 and PZ-10 contained the greatest thicknesses of LNAPL and would be suitable for the pilot test. The bail down pre-test was performed by lowering dedicated tubing into the layer of LNAPL above the water table in piezometer PZ-7. A Solinst Model 410 peristaltic pump was connected to the down-hole tubing, and LNAPL was purged rapidly from the well into nearby IDW drums. LNAPL pumping ceased after removing 82% of the original LNAPL thickness, or 5.7 liters (1.5 gallons) of LNAPL.

Product thickness was continuously measured in PZ-7 and adjacent piezometers using an electric tape oil/water interface probe to evaluate the LNAPL recharge rates and LNAPL thickness changes at surrounding piezometers after cessation of pumping. LNAPL thickness measurements were collected until 80% of the original LNAPL thickness was recovered in PZ-7. Results of this test are discussed in Section 5.3.1. The data collected during this test was used to assess the suitability of the existing wells and piezometers for the LNAPL recovery tests, develop pumping equipment specifications, and determine the anticipated duration of the LNAPL recovery tests, subsequently performed between April 15, 2008, and April 17, 2008.

LNAPL Recovery Testing

LNAPL recovery testing began on April 15, 2008, and was conducted over a 3-day period. During this time, three separate LNAPL recovery tests at three separate wells were completed using two different LNAPL recovery pumps from different manufacturers.

Four pressure transducers were installed in four separate piezometers prior to each LNAPL recovery test to monitor the drawdown and recovery rate of product and water accumulation in the wells. An additional barometric pressure transducer was installed in the headspace above the water table in PZ-6 to measure ambient atmospheric pressure throughout the duration of the LNAPL recovery tests. These barometric data were used to correct the water levels recorded in the pressure transducers, compensating for fluctuations in ambient atmospheric pressure conditions. Each transducer was configured to collect pressure readings at linear time intervals of 15-second increments. Data collection began prior to initiating pumping and continued through LNAPL recovery and overnight into the following morning. The transducer data are included in Appendix 4.

Manual water level and LNAPL thickness measurements were also gathered from the wells with transducers and the adjacent piezometer well network in order to calibrate the transducers' response in terms of depth to water and LNAPL thickness. These data were collected prior to and during each recovery test. The manual measurement data are included in Appendix 4.

The LNAPL recovery tests were performed following the method described by Huntley (2000). For each piezometer, initial (static) measurements of the LNAPL/air interface (depth to LNAPL) and the LNAPL/water interface (depth to water) were collected with an interface probe to determine the depth and thickness of the LNAPL in the piezometer prior to the test. A pump was then lowered into the piezometer and the LNAPL was pumped from the piezometer casing. To perform an accurate test of LNAPL recovery, only the LNAPL was removed from the piezometer, and every effort was made not to disturb the groundwater surface. After the majority of the LNAPL was removed from the piezometer, the interface probe was used to monitor the LNAPL and water levels over time. These depths to the top of the LNAPL and the top of the water were recorded until either the LNAPL thickness had returned to near its original value, or for approximately 24 hours, whichever came first.

LNAPL Recovery Test 1 at MW-3

LNAPL recovery pumping commenced on April 15, 2008, using a 3-inch-diameter ADJ 1010 pump from Xitech Instruments to pump LNAPL from MW-3. MW-3 was selected for the first LNAPL recovery test based on the presence of LNAPL and the larger diameter requirements of the LNAPL pump.

The pump removed 1 liter of product over 11 minutes at a rate of 75 mL/min, which reduced the original product thickness in MW-3 from 0.38 foot to 0.05 foot.

Pressure transducer data from PZ-4, PZ-7, PZ-8, and PZ-10 were collected continuously throughout the test and LNAPL recovery period. The location of each transducer was selected because of its close proximity to the pumped well and to gather data from wells with varying degrees of LNAPL thickness. The large diameter size of the Xitech LNAPL pump prohibited the installation of a transducer in the pumped well, MW-3. Product thickness measurements were collected until LNAPL and water level equilibrium was reached. A confirmatory round of LNAPL thickness measurements was collected the following day from the wells included in the study. The recovery test was completed on April 15, 2008.

LNAPL Recovery Test 2 at PZ-7

The second LNAPL recovery test was completed at piezometer PZ-7 on April 16, 2008. PZ-7 was utilized during this test since it contained the greatest thickness of LNAPL in the study area. A QED AutoPump Model AP2 pump was used.

The pump removed 3.75 liters of product over 20 minutes at a rate of 190 mL/min, which reduced the original product thickness in PZ-7 from 6.41 feet to 0.7 foot.

Throughout the test, transducer pressure data were collected from PZ-7 (the pumping well), PZ-8, PZ-10, and MW-3. Product thickness measurements were collected until LNAPL and water level equilibrium were reached. A confirmatory round of LNAPL thickness measurements were collected the following day from all wells included in the study. The recovery test was completed on April 16, 2008.

LNAPL Recovery Test 3 at PZ-10

On April 17, 2008, a third LNAPL recovery test was performed at piezometer PZ-10. The same QED AutoPump Model AP2 pump was utilized to pump LNAPL from the well.

The pump removed 3.75 gallons (14.2 liters) of product over 27 minutes at a rate of 200 mL/min, which reduced the original product thickness in PZ-10 from 6.14 feet to 0.13 foot.

While pumping from PZ-10, transducer pressure data were recorded continuously from the pumped well (PZ-10) and three closest wells: PZ-11, PZ-8, and MW-3. These wells were selected for installation of transducers because of their close proximity to the pumped well and the thickness of the LNAPL in the wells. Product thickness measurements were collected until LNAPL and water level equilibrium was reached. A confirmatory round of LNAPL thickness measurements was collected the following day from the wells included in the study. The recovery test was completed on April 16, 2008.

5.2.4 LNAPL Characterization Sampling

At the conclusion of the LNAPL recovery pilot tests, a sample of the LNAPL was collected directly from PZ-10 for characterization purposes. The LNAPL characterization sample (FP-PZ-10-2) was collected using a dedicated Teflon® bailer. The sample was collected in accordance with the UFP-QAPP and analyzed through Chemtech Laboratories for TCL VOCs, SVOCs, pesticides, PCBs, and TAL metals. The results of these analyses are discussed in the next subsection.

In addition, a sample of the LNAPL was collected from the drum where the LNAPL from the recovery tests was collected. This sample was for waste characterization purposes and was analyzed by Chemtech for TCLP, ignitability, and reactivity characteristics. The results from the waste characterization analyses are discussed in Section 7.

5.3 Results of LNAPL Recovery Test and LNAPL Chemical Composition

5.3.1 Results of Water Level and LNAPL Thickness Measurements

As discussed in the Phase 1 RI TM, two factors have a significant influence on the water table at the Diamond Head site. The first is the presence of delineated wetlands in the southeast corner and along the southern boundary of the site. These areas have historically been observed to range from dry to inundated with over 30 inches of standing water. The second factor influencing groundwater conditions is the presence of the LNAPL plume in the southeast corner of the site in the area of the former lagoon. Although lighter than water,

the density of the LNAPL has the effect of depressing the water table and influences groundwater flow.

Note that the water elevation data in Figures 5-1 and 5-2 are presented relative to mean sea level (msl), and that water elevations in wells containing LNAPL have been corrected for the presence of the site LNAPL. The observed water elevations are generally consistent with those observed during the Phase 1 RI. An area of high groundwater elevation occurs in the southeast corner of the site (MW-3 area), and groundwater flows radially away from this high toward the northeast, northwest, and southwest. Limited data are available for areas to the south and southeast, but indications are that groundwater also flows radially away from the mounded area in these directions also. Although corrected for the presence of the site LNAPL, the water level measurements observed in January 2008 at wells MW-13S and PZ-14 indicate the presence of a slight depression in the water table of approximately 0.3 foot. While only observed in the January measurements, this occurrence is consistent with similar observations during the Phase 1 RI.

LNAPL thickness contours are presented in Figures 5-3 and 5-4. As discussed above, the high viscosity of the LNAPL made collection of thickness measurements time consuming, because the product coated the probe and multiple measurements were required to demonstrate reproducibility. The occurrence of LNAPL is also generally consistent with that noted during the Phase 1 RI in 2003, with the following deviations. While variations in LNAPL thickness are noted between measurement events within the same well, and large variations in measured thickness can be observed over short distances between wells, the maximum thickness of LNAPL observed in 2008 is approximately 1 foot greater than observed in 2003. For example, the maximum thickness observed in April 2008 was 6.09 feet occurring at piezometer PZ-7, while the maximum thickness observed in August 2003 was 5.02 feet at adjacent piezometer PZ-8. All the piezometers and wells where LNAPL is observed were installed during the Phase 1 RI activities in 2003, except for well MW-3, which is from earlier activities in 1989.

Increases in the in-well LNAPL thicknesses were also observed in well MW-13S that contained between 0.07 to 1.9 feet of LNAPL in 2003 and was measured to contain approximately 4.6 feet of LNAPL in 2008. Similarly, piezometer PZ-14 had an increase from 0.06 foot of LNAPL in 2003 to 0.4 foot in 2008. Piezometer PZ-16, which was measured as not containing LNAPL in 2003, was found to contain approximately 0.2 foot in 2008. Overall, measurable LNAPL is observed in wells in three separate areas in 2008 and these same areas can be seen in the 3-D graphic of the LNAPL occurrence generated from the LIF data presented in Figure 4-9.

The areas of the site where measurable LNAPL is currently present are: 1) the main plume around piezometers PZ-7 and PZ-10, 2) a second area between MW-13S and PZ-14, and 3) a newly observed occurrence at PZ-16. This new observation of LNAPL in PZ-16 in 2008 compared to the lack of LNAPL observed during Phase 1 in 2003 may be related to the high-viscosity of the LNAPL and potentially long time that is required for the LNAPL to achieve a steady-state (and measurable) thickness in the piezometer. During the relatively short period of field activities during Phase 1, the high-viscosity LNAPL may not have reached the well in sufficient volume to be measured.

5.3.2 Results of the LNAPL Recovery Tests

The mechanics of an LNAPL bail down test produce data that are averaged for the formation. An average result is because of the fairly large thickness of LNAPL and the length of the well screen and the subsurface interval that is being bailed. While the tests

performed were relatively short for an LNAPL of such high viscosity, two of the three LNAPL recovery tests produced viable data for evaluating the hydraulic characteristics of the material. Test # 1 performed at well MW-3 was ineffective because of the shallow thickness of LNAPL in the well. This test, however, provided a positive evaluation of the performance of the Xitech remediation pump. Bail down tests were successfully performed during Test #2 at piezometer PZ-7 and Test #3 at piezometer PZ-10, allowing for the determination of subsurface conductivities and transmissivities associated with the LNAPL found at these locations. These parameters help describe the potential mobility and, ultimately, the potential recoverability, of the LNAPL found in the subsurface.

The time/drawdown data generated from the pumping well during the bail down test were analyzed in this evaluation. Drawdown and recovery were either not observed in surrounding piezometers or insufficient to be included in the analysis. The analysis was performed using a modified form of the Bouwer and Rice slug test analysis as presented in Huntley (2000) to generate an LNAPL conductivity (K_o) and LNAPL transmissivity (T_o). The modification of the Bouwer and Rice analysis comes from the fact that the equations for the analysis were derived for a single phase (water). The inclusion of a second phase (LNAPL) requires the results to be "corrected" to account for the second phase; specifically, the results are corrected by the reciprocal of the difference between the density of the two fluids (water and LNAPL). For both bail down tests, the required condition of a nearly constant piezometric surface (corrected water table) following the "instantaneous" removal of the LNAPL from the piezometer was met during the period of data analysis. The bail down test analysis spreadsheets and graphs are presented in Appendix 4.

The calculated results of the LNAPL bail down tests at piezometers PZ-7 and PZ-10, located approximately 30 feet apart, were fairly similar and indicated the following subsurface conductivity and transmissivity for the LNAPL. For comparison, the data were also evaluated to provide a maximum range of conductivity values over "worst case" scenarios where drainage was assumed to come either entirely from the well gravel pack or entirely from the formation. :

- PZ-7: Conductivity for LNAPL (K_o) = 1.49×10^{-5} cm/sec
 (maximum K_o range: 5.2×10^{-6} cm/sec and 4.2×10^{-5} cm/sec)
 Transmissivity for LNAPL (T_o) = 2.91×10^{-3} cm²/sec
- PZ-10: Conductivity for LNAPL (K_o) = 2.12×10^{-5} cm/sec
 (maximum K_o range: 3.4×10^{-5} cm/sec and 1.52×10^{-5} cm/sec)
 Transmissivity for LNAPL (T_o) = 3.96×10^{-3} cm²/sec

The calculated K_o values can be combined with an LNAPL gradient, an associated LNAPL saturation, and porosity to generate an effective LNAPL velocity. For example, using the conductivity for LNAPL calculated for piezometer PZ-7 (1.49×10^{-5} cm/sec), and assuming a conservatively high LNAPL gradient of 0.01 (1 foot vertical change over 100 feet of horizontal distance), a total porosity of 66% (average from PZ-7 lab data), and an LNAPL saturation of 25% (average of PZ-7 lab data), the effective LNAPL velocity is calculated to be 9×10^{-7} cm/sec, or approximately 1 foot per year. It should be noted, however, that this example calculation is highly simplified, because each of these parameters vary throughout

the subsurface, both horizontally and vertically. Overall, the bail down test results from piezometers PZ-7 and PZ-10 suggest, in very rough terms, that the LNAPL found in these wells has very limited mobility. It should be noted that because of the difficulty in collecting measurements of this viscous LNAPL, there is uncertainty associated with the analysis, which was addressed through the assumption that recovery data are representative of the formation and not from the sand pack material surrounding the well screen.

5.3.3 Results of Characterization Sampling

Table 5-1 shows the organic compounds (volatile, semivolatile, and PCBs) that were detected in the LNAPL sample collected from PZ-10. Table 5-2 shows the metals and cyanide present in this sample. Only detectable analyte concentrations are included in these tables. Complete analytical results can be found in Appendix 4.

As expected, benzene, toluene, ethylbenzene, and xylenes, as well as a number of other volatile and semivolatile organic compounds consistent with a petroleum matrix, were found in the sample. Two PCBs (Arochlor 1232 and Arochlor 1260) were also measured at elevated concentrations). A variety of metals, including lead, as well as cyanide, was also detected in the sample.

These results are consistent with the results for the LNAPL sample collected from monitoring well MW-3 during the Phase 1 RI, as well as with the Phase 1 characterization results that the LNAPL contains more diesel range organics (DROs) than the gasoline range organics (GROs). The results of the testing of the oil for hazardous waste characteristics are discussed in Section 8.

It should be noted that, although the LNAPL from PZ-10 was shown to contain these contaminants, none of them exceeded leachability criteria when an LNAPL-containing soil sample from this same location was exposed to the SPLP test. It appears, therefore, that most of the contamination is bound to soil or contained within the pores of the matrix that are not susceptible to strong dissolution processes. Refer to Section 4.3.2 for more information on the SPLP results.

Of note, the analyses of the LNAPL sample had been planned by method SOM01. Because of the nature of the sample matrix, the laboratory indicated they could not complete the analysis using this method. The sample was instead analyzed by SW-846 methods, with the sample needing to be diluted for some of the analyses (resulting in higher detection limits) and the results being reported in solid units. Specifically, the samples for VOC and SVOC analyses were diluted 100 and 10 times, respectively. It is possible that compounds are present in the sample that were not detected at the detection levels achieved for the diluted samples.

5.3.4 Summary

The following summarizes the results from the LNAPL recovery test:

Water Level and LNAPL Thickness Measurements:

- Two factors have a significant influence on the water table at the Diamond Head site: 1) the presence of delineated wetlands in the southeast corner and along the southern boundary of the site, and 2) the presence of the LNAPL plume in the southeast corner of the site in the area of the former lagoon which has the effect of depressing the water table and influencing groundwater flow.

- The observed water elevations are generally consistent with those observed during the Phase 1 RI.
- An area of high groundwater elevation occurs in the southeast corner of the site (MW-3 area), and groundwater flows radially away from this high toward the northeast, northwest, and southwest. Limited data are available for areas to the south and southeast, but indications are that groundwater also flows radially away from the mounded area in these directions.
- The LNAPL compensated water level measurements observed in January 2008 at wells MW-13S and PZ-14 indicate the presence of a slight depression in the water table of approximately 0.3 foot. While only observed in the January measurements, this occurrence is consistent with similar observations during the Phase 1 RI.
- The occurrence of LNAPL is generally consistent with that noted during the Phase 1 RI in 2003.
- While variations in LNAPL thickness are noted between measurement events within the same well, and large variations in measured thickness can be observed over short distances between wells, the maximum thickness of LNAPL observed in 2008 is approximately 1 foot greater than observed in 2003.
- Measurable LNAPL is observed to occur in three separate areas in 2008—the main plume around piezometers PZ-7 and PZ-10, a second area between MW-13S and PZ-14, and a newly observed occurrence at PZ-16.

LNAPL Recoverability Assessment:

- Two of the three LNAPL recovery tests produced viable data for evaluating the hydraulic characteristics of the material. Bail down tests were successfully performed in Test #2 at piezometer PZ-7 and Test #3 at piezometer PZ-10, while Test # 1 at MW-3 did not produce viable data because of the shallow thickness of LNAPL in the well.
- The calculated results of the LNAPL bail down tests at piezometers PZ-7 and PZ-10, located approximately 30 feet apart, were fairly similar and indicated the following subsurface conductivity and transmissivity for the LNAPL. For comparison, the data were also evaluated to provide a maximum range of conductivity values over "worst case" scenarios where drainage was assumed to come either entirely from the well gravel pack or entirely from the formation:
 - PZ-7: Conductivity for LNAPL (K_0) = 1.49×10^{-5} cm/sec
 (maximum K_0 range: 5.2×10^{-6} cm/sec and 4.2×10^{-5} cm/sec)
 Transmissivity for LNAPL (T_0) = 2.91×10^{-3} cm²/sec
 - PZ-10: Conductivity for LNAPL (K_0) = 2.12×10^{-5} cm/sec
 (maximum K_0 range: 3.4×10^{-5} cm/sec and 1.52×10^{-5} cm/sec)
 Transmissivity for LNAPL (T_0) = 3.96×10^{-3} cm²/sec
- The calculated K_0 values can be combined with an LNAPL gradient, an associated LNAPL saturation, and porosity to generate an effective LNAPL velocity. For example,

using a combination of site data and standard reference values, the effective LNAPL velocity at PZ-7 is calculated to be 9×10^{-7} cm/sec, or approximately 1 foot per year. It should be noted, however, that this example calculation is highly simplified, because each of these parameters vary throughout the subsurface, both horizontally and vertically.

- Overall, the bail down test results from piezometers PZ-7 and PZ-10 suggest that the LNAPL found in these wells has very limited mobility.

LNAPL Characterization Sampling:

- As expected, benzene, toluene, ethylbenzene, and xylenes, as well as a number of other volatile and semivolatile organic compounds consistent with a petroleum matrix, were found in the characterization sample from PZ-10.
- Two PCBs (Arochlor 1232 and Arochlor 1260) were also measured in the PZ-10 sample at elevated concentrations.
- A variety of metals, including lead and cyanide, were also detected in the PZ-10 sample.
- These results are consistent with the results for the LNAPL sample collected from monitoring well MW-3 during the Phase 1 RI, as well as with the Phase 1 characterization results that the LNAPL contains more DROs than the GROs. It should be noted that, although the LNAPL from PZ-10 was shown to contain these contaminants, none of them exceeded leachability criteria when an LNAPL-containing soil sample from this same location was exposed to the SPLP test discussed in Section 4. Thus, most of the contamination is bound to soil particles or contained within the pores of the matrix which are not susceptible to strong dissolution processes.

SECTION 6.0

LNAPL Mobility and Recoverability Evaluation

Section 6 describes the following:

1. The purpose and scope of the LNAPL mobility and recoverability evaluation
2. Intact soil core sampling for the purpose of characterizing the mobility and recoverability of the LNAPL
3. Data reduction and calculations used to perform the LNAPL mobility and recoverability evaluation
3. The results of the LNAPL mobility and recoverability evaluation

6.1 Purpose and Scope

The LNAPL mobility and recoverability evaluation provided the third line of evidence to the characteristics of the LNAPL found at the site based on specialty laboratory testing. The evaluation examines the relationship between the determined characteristics and the nature of the subsurface soil matrix where the LNAPL occurs and assesses the mobility of the LNAPL under ambient conditions and the practicality of its removal. Specific objectives of the evaluation included:

- Assess the mobility (i.e., pore fluid velocity) and recoverability of the LNAPL at three diverse locations at the site including areas of high, medium, and low LIF response
- Assess the extent of potentially mobile LNAPL by correlating mobility with LIF results

The evaluation was performed and the objectives were met through performing specialty sampling for petroanalysis which included:

- Installing conventional soil borings in order to collect intact core samples for specialty testing
- Collecting LNAPL and groundwater pair samples from select monitoring wells for specialty testing.

6.2 Sampling and Analysis Activities

6.2.1 Field Sampling Approach

As discussed in Section 4, a limited conventional soil boring program was implemented in conjunction with the LIF investigation to, along with objectives from the LIF investigation, collect soil cores and LNAPL and groundwater sample pairs for specialty laboratory testing. The objective was to gather data to evaluate the LNAPL in terms of its potential mobility and recoverability. The locations of the soil borings and sampling points are shown on Figure 1-2.

6.2.1.1 Intact Core Sampling

EPI utilized a Geoprobe™ DPT rig between March 18 and 19, 2008 to collect intact soil core samples from four locations adjacent to LIF delineation points of high (two intervals), medium, and low %RE response as described in the table below. The results were used to help estimate the potential in-situ mobility and recoverability of the LNAPL in conjunction with the LNAPL recovery tests.

LIF Boring Location	Intact Core Depth Interval (Feet bgs)	LNAPL Depth Horizon	Sample Characteristics
LIF-40	0' – 5'	Shallow	Low-medium concentration (2%RE low, 30%RE avg, 53%RE max)
LIF-32	1' – 5'	Shallow	Medium-high concentration (0.3%RE low, 31%RE avg, 141%RE max)
LIF-5	8' – 15'	Deep	High Concentration (1%RE low, 27%RE avg, 174%RE max)
LIF-CAL-PZ-7	9' – 13'	Deep	High concentration (6%RE low, 80%RE avg, 196%RE max)

Intact soil core samples were collected within clear acetate MacroCore™ sleeves extending from approximately 1 foot above the LNAPL smear in the unsaturated zone to 1 foot below the LNAPL smear in the saturated zone. Upon collection of the acetate sleeve, each core was immediately capped, packed and flash-frozen with dry ice to "lock" the pore fluids, soil grains and LNAPL in place. The frozen core was then shipped overnight to PTS Laboratories, Inc. of Santa Fe Springs, California, a specialty laboratory for LNAPL mobility and recoverability evaluation. Only soil cores with greater than 75% recovery were shipped to the laboratory for analysis. If less recovery was initially achieved, the original boring location was abandoned and a boring was advanced immediately adjacent to the original boring.

Upon receipt of the frozen cores, the laboratory cryogenically cut the length of each core to expose the soil profile and photographed them under white light (color photography) and ultraviolet light. Following review of the color and UV photographs by CH2M HILL, a Pore Fluid Saturation (PFS) analysis package was performed at select locations in the cores. The PFS package included analysis of LNAPL and water saturation [%], total porosity, air-filled porosity, dry bulk density, and grain density. The photographs and PFS data are provided in Appendix 5. Upon review of the PFS data, a Drainage Capillary Pressure Test (DCPT) was then performed at select locations containing the maximum LNAPL saturation. The DCPT data is also provided in Appendix 5.

Additionally, two Free Product Mobility (centrifuge method) tests were performed on each of the four cores, one from the vadose zone and one from the saturated zone. Three different pressures were used for each test to simulate in situ conditions under which LNAPL may mobilize (ambient, remediation-induced, and maximum practical). The results of these tests are presented in Appendix 5 and were used to assess residual LNAPL saturation levels

under various conditions in the vadose and saturated zones. Finally, two grain size distribution analyses and two total organic carbon (TOC) analyses were completed per core sample and the data is presented in Appendix 5.

Analytical results of each test performed are discussed in Section 6.3.

6.2.1.2 LNAPL/Groundwater Pair:

In addition to the soil cores, a groundwater and LNAPL sample pair was collected from two well locations within the LNAPL plume. The wells selected for each sample pair were MW-13S and PZ-7. At each monitoring well, a sample of LNAPL and water were collected (and bottled separately) from the LNAPL water interface. Each sample pair was collected using a peristaltic pump such that the LNAPL sample was free of water and the water sample was free of LNAPL. Dedicated tubing was used at each sampling location to eliminate cross contamination. An LNAPL Fluid Properties Analysis package was performed on each water/LNAPL sample pair by PTS Laboratory. This analysis included dynamic viscosity, fluid density at three temperatures, surface tension for each fluid, and interfacial tension (three phase pairs; oil/water, oil/air, and water/air). Data is provided in Appendix 5. The results were used in conjunction with the LNAPL mobility and recovery test results as discussed in Section 6.3.

6.2.1.3 Survey Data

At the conclusion of the intact soil core sampling activities, spatial information of interest was recorded by CH2M HILL at each soil boring location using a Trimble GeoXT w/ GeoBeacon to an accuracy of less than 1 meter. The spatial information collected is presented in Appendix 3.

6.2.2 Petrophysical Laboratory Analysis

Upon receipt of the frozen soil core samples, PTS Laboratories performed analyses in the following specific order under the direction of CH2M HILL to build an incremental data set that expanded upon the results of previous analyses. The incremental approach to analysis allowed for the DCPTs to be performed at the appropriate depth intervals after confirming the general condition of cores (photographic review) and observing the PFS profiles for saturation peaks and potential LNAPL mobility fronts.

PhotoLog™ Digital Core Photography – Frozen cores were initially cryogenically cut in half along the long axis to expose the soil profile. The entire length of all cores was photographed under white light (color photography) and ultraviolet light. Upon collection of the color and UV photographs, the laboratory e-mailed the core photographs to CH2M HILL and paused for instruction prior to performing any further analyses.

Pore Fluid Saturation (PFS) – A total of 33 samples locations were analyzed including locations 1 foot above and 1 foot below the LNAPL smear zone (as identified by field observations, LIF results, and photographic review provided by CH2M HILL). Analyses in the Pore Fluid Saturation suite included:

- LNAPL saturation (%)
- Water saturation (%)
- Total porosity
- Air-filled porosity
- Dry bulk density
- Grain density

- Moisture content

Drainage Capillary Pressure Test (LNAPL/Water phase) – Analysis of one LNAPL/Water set per core (4 tests total). Analysis package included:

- Initial fluid saturation
- Residual fluid saturation
- Final water production vs. capillary pressure
- Effective (total) porosity
- Bulk density
- Permeability
- Hydraulic conductivity

Drainage Capillary Pressure Test (Air/Water phase) – Analysis of one Air/Water set per core (4 tests total). Analysis package included:

- Initial fluid saturation
- Residual fluid saturation
- Final water production vs. capillary pressure
- Effective (total) porosity
- Bulk density
- Permeability
- Hydraulic conductivity

Following the DCPTs the following analyses were also completed:

Free Product Mobility (centrifuge method) – Four sample locations were analyzed using centrifugal force applied at a worst case condition up to 1,000 times gravity. Force was applied for as long as necessary to reach maximum mobility (up to one hour or until no additional product was released from the sample) to demonstrate product mobility. This analysis suite also included initial and residual pore fluid saturations, porosity, and bulk density.

Grain size analysis – A total of six grain size analyses were performed at the peak LNAPL saturation and other pertinent depth intervals to evaluate the variation in gradation between the cores. Analysis was conducted using 16 dry sieve screens from 1" to 400 mesh. Laser particle size analysis (LPSA) method and/or hydrometer were also utilized from 2mm to <1 micron.

Total Organic Carbon (Walkley-Black method) – A total of six analysis were performed on samples at the peak LNAPL saturation and another pertinent depth interval in each core.

LNAPL Fluid Properties Package - Following receipt of the two LNAPL/Groundwater sample pairs, PTS Laboratories performed the following analyses:

- Dynamic viscosity at three temperatures,
- Fluid density at three temperatures,
- Surface tension for each fluid
- Interfacial tension (three phase pairs; oil/water, oil/air, and water/air)

6.3 Results of LNAPL Mobility and Recoverability Evaluation

This section describes the analysis and results of the mobility and recoverability assessment performed for the LNAPL that exists at the site.

6.3.1 LNAPL Mobility Assessment

An analysis of the potential mobility of the in situ LNAPL in subsurface soils at the site was conducted using laboratory analytical results for a representative set of fluid and soil samples collected from the site (all laboratory analyses presented below were performed by PTS Laboratories, Inc. of Santa Fe Springs, California). Appendix 5 contains the detailed spreadsheet calculations performed for the LNAPL mobility assessment presented herein.

An estimate of LNAPL mobility was performed for four locations at four different depth intervals as marked on Figure 1-2 with "Intact Core Sample" symbols (LIF-040, LIF-32, LIF-CAL-PZ-7, and LIF-005). In general, analyses were performed at the locations of peak LNAPL saturations to understand the potential mobility at the locations and depths where LNAPL is most likely to be mobile. It should be noted that the mobility assessment and data analysis discussed below is considered highly site-specific because all of the data used were generated from the laboratory analysis of intact core samples that are inferred to be representative of in situ conditions at the site.

6.3.1.1 Capillary Pressure Test Data Analysis

Raw Capillary Pressure Data

The first step of the mobility analysis involved using the raw DCPT data from each of the soil samples to estimate the theoretical van Genuchten curve-fitting parameters using the following equation (van Genuchten, 1980):

$$S = (1 - S_r) \left[\frac{1}{1 + [\alpha (P_c / \gamma_w)]^N} \right]^{\left(1 - \frac{1}{N}\right)} + S_r$$

where S is the fluid saturation, S_r is the residual saturation, P_c / γ_w is the capillary pressure head (cm), and N and α (cm^{-1}) are model fitting parameters.

The van Genuchten parameters (α and N) are used to fit the equation to the laboratory DCPT data (the parameter α is roughly the inverse of the capillary fringe height and N is a measure of the slope of the curve). In addition, the residual water saturation is estimated as part of the curve-fitting analysis. The resultant curve-fitting parameters are presented in Table 6-1.

The two-phase (air and water) van Genuchten equation was modified by the work of Farr *et al.* (1990) and Lenhard and Parker (1990) to account for a third phase (LNAPL). Thus, under vertical equilibrium, water saturation (S_w) and LNAPL saturation (S_o) are given by:

$$S_w = (1 - S_r) \left[\frac{1}{1 + [\alpha_{ow} (P_c^{ow} / \gamma_w)]^N} \right]^{(1 - \frac{1}{N})} + S_r$$

$$S_o + S_w = (1 - S_r) \left[\frac{1}{1 + [\alpha_{ao} (P_c^{ao} / \gamma_w)]^N} \right]^{(1 - \frac{1}{N})} + S_r$$

where α_{ow} is the van Genuchten parameter for an LNAPL/water system, and α_{ao} is the van Genuchten parameter for an air/LNAPL system.

By scaling the van Genuchten parameter, α_{aw} , for an air/water system (the α generated from the curve fit), the LNAPL/water (α_{ow}) and air/LNAPL (α_{ao}) parameters can be calculated as:

$$\alpha_{ow} = \alpha_{aw} \left(\frac{\sigma_{aw}}{\sigma_{ow}} \right); \quad \alpha_{ao} = \alpha_{aw} \left(\frac{\sigma_{aw}}{\sigma_{ao}} \right)$$

where σ_{aw} is the air/water surface tension (dyne/cm), σ_{ow} is the LNAPL/water surface tension (dyne/cm), and σ_{ao} is the air/LNAPL surface tension (dyne/cm).

The modified form of the van Genuchten equation was used to estimate the theoretical LNAPL saturation profile above the LNAPL/water interface using the laboratory capillary pressure data. This correlation was then used to determine the relationship between LNAPL saturation and mobility.

Table 6-1 presents the generated curve-fitting parameters, along with other fluid and soil parameters necessary for the hydrocarbon mobility analysis presented below. The table presents the parameters generated from the four soil samples collected and analyzed for site-specific capillary characteristics, along with the parameters generated from an LNAPL sample collected from piezometer PZ-7.

LNAPL Saturation Profiles

Using the equations presented above, theoretical LNAPL saturation curves were generated for each of the four soil samples. The theoretical LNAPL saturation profiles estimated in this evaluation using the raw capillary pressure data are presented in Appendix 5. An example theoretical LNAPL saturation profile above the LNAPL/water interface using the laboratory capillary pressure data is presented in Figure 6-1.

Conceptually, these theoretical LNAPL saturation profile figures can be interpreted as follows: at the LNAPL/water interface, the theoretical fluid saturation is 100 percent and consists completely of water-filled pores (100 percent water saturation, zero LNAPL saturation, zero air). As the elevation above this interface increases, the LNAPL saturation increases (and consequently the water saturation decreases) to a maximum near the LNAPL/air interface. Between the LNAPL/water interface and the LNAPL/air interface, the theoretical fluid saturation is assumed to be 100 percent and is made up of LNAPL and water. Above the LNAPL/air interface (and within the LNAPL capillary fringe), the total

saturation consists of LNAPL, water, and air, until at some elevation above this interface, only air and water occupy the pore spaces.

As shown in Figure 6-1, the maximum theoretical LNAPL saturation value for sample LIF-PZ7-09-13-2 at a depth of 10.6 feet bgs was 9.0 percent. Based on the field pore-fluid saturation (PFS) results, the maximum measured LNAPL saturation at this location was 44.1 percent (the measured LNAPL saturation at this location at 10.6 feet bgs was 43.8 percent). Three of the four theoretical LNAPL saturation profiles generated from the raw capillary pressure data showed similar results. That is, the theoretical LNAPL saturations were significantly lower than the measured saturations. Therefore, the need for "refining" the curve-fitting parameters to better correlate with the measured LNAPL saturations was evaluated.

Comparison of Theoretical LNAPL Saturation Curves and Measured Pore Fluid Saturations

The theoretically-generated LNAPL saturation curves were compared to the measured PFS profiles (Appendix 5) to evaluate whether the theoretical values were representative and appropriate for making conclusions on LNAPL mobility. Of the four locations evaluated, only the theoretical saturations from one location (LIF-032-01-05-2) were reasonably close to the measured saturations. Therefore, the van Genuchten parameters were tuned to more closely fit the measured PFS data. Specifically, the measured PFS profile at each location was used to estimate a depth to the LNAPL/water interface, and then the curve was fit to closely match the measured saturations using the SOLVER function in Microsoft Excel. The SOLVER curve fits were manually adjusted to provide a better correlation between the maximum LNAPL saturation values (measured versus generated), thus providing a more representative estimate of LNAPL mobility. Table 6-2 presents the maximum LNAPL saturations measured in the field versus the maximum LNAPL saturations generated from the raw capillary pressure data curve fit and the refined curve fit.

The model parameters that were adjusted in the refined curve fit included the van Genuchten parameters (α_{ow}) and N, and the presumed depth to the LNAPL/water interface (the residual water saturation was held constant at 0.25 based on the raw data and to provide a better correlation to the maximum measured LNAPL saturations). It was assumed that the measured PFS profiles were representative, and laboratory sub-sampling and analytical procedures may have introduced non-representative bias. The refined van Genuchten parameters (Table 6-3) were used in the equations presented above to generate an LNAPL saturation profile above the LNAPL/water interface (Appendix 5). In each case, while the overall curve fits were reasonably close, the refined parameters produced a maximum LNAPL saturation greater than the actual measured maximum saturation, which ultimately allowed for a more conservative estimate of LNAPL mobility using these results.

The theoretical LNAPL saturation profiles estimated in this evaluation using the refined van Genuchten parameters are included in Appendix 5. As an example, the theoretical LNAPL saturation profile above the LNAPL/water interface using the refined curve fit parameters and measured LNAPL saturations for location LIF-PZ7-09-13-2 is presented in Figure 6-2. This figure also includes the measured LNAPL saturations (using the estimated depth to the LNAPL/water interface) for comparison and shows the closer correlation following refinement of the curve-fitting parameters.

The LNAPL mobility analysis described below was performed using both sets of curve-fitting parameters for comparison purposes; however, because the refined curve fit parameters provided a closer match to the field measured PFS profiles, the results from the refined parameters are considered more representative of actual conditions.

6.3.1.2 LNAPL Relative Permeability and Conductivity

The parameters shown in Tables 6-1 and 6-3 were used to generate theoretical LNAPL saturation curves and plots of LNAPL conductivity versus LNAPL saturation for each of the soil samples (Appendix 5). LNAPL collected from piezometer PZ-7 was analyzed by the laboratory for density, viscosity, and interfacial tension pairs; these values were used to represent the LNAPL found at the site. Results of the data analysis are presented below for both the raw capillary pressure data and the refined curve-fitting parameters.

LNAPL relative permeability is exponentially related to LNAPL saturation. In other words, as LNAPL saturation decreases, the relative permeability of the LNAPL decreases exponentially. The relative permeability of the LNAPL (k_{ro}) in a three-phase system (air, water, LNAPL) can be calculated using the Mualem expression (Parker, 1989):

$$k_{ro} = (\bar{S}_t - \bar{S}_w)^{1/2} \left[\left(1 - \bar{S}_w^{1/m} \right)^m - \left(1 - \bar{S}_t^{1/m} \right)^m \right]^2$$

where:

$$\bar{S}_w = \frac{S_w - S_r}{1 - S_r} \qquad \bar{S}_t = \frac{S_t - S_r}{1 - S_r}$$

S_w = water saturation, S_t = total fluid saturation, S_r = residual saturation, and
 $m = 1 - (1/N)$.

The LNAPL conductivity (K_{LNAPL} ; cm/sec) is a measure of the soils' ability to transmit hydrocarbon fluids. It can be calculated as:

$$K_{LNAPL} = k_{ro} K_{sat} \left(\frac{\rho_o / \rho_w}{\mu_o / \mu_w} \right)$$

where k_{ro} is the LNAPL relative permeability, K_{sat} is the saturated hydraulic conductivity (cm/sec), ρ_o is the LNAPL density (g/cm³), ρ_w is the water density (g/cm³), μ_o is the LNAPL viscosity (g/cm sec), and μ_w is the water viscosity (g/cm sec).

Appendix 5 includes the tables and figures showing the LNAPL relative permeability and theoretical LNAPL conductivity values calculated for each soil sample over the entire range of elevations above the LNAPL/water interface. The maximum values for each parameter are presented in Table 6-4.

As shown in Table 6-4, the results for all samples and both sets of curve-fitting parameters are fairly similar, ranging from a high of 8.32×10^{-7} cm/sec in the fine sand at 2.2 feet bgs in LIF-032-01-05-2 (peak measured LNAPL saturation of 36.6 percent) to a low of 3.04×10^{-8} cm/sec in the fine sand at 10.2 feet bgs in LIF-005-08-15-2 (peak LNAPL saturation of 39.5 percent) and 5.49×10^{-8} cm/sec in the silt at 10.6 feet bgs in LIF-PZ7-09-13-2 (peak LNAPL saturation of 44.1 percent). In general, LNAPL conductivities less than 1×10^{-6} cm/sec are essentially considered non-conductive. As a point of reference, a hydraulic conductivity of 1×10^{-6} cm/sec is the design standard for hazardous waste landfill liners that are intended to act as impermeable barriers to contain landfill leachate.

The maximum LNAPL conductivities show some consistency with expected results. The two shallow samples (LIF-040-00-05-2 at 0.8 foot bgs and LIF-032-01-05-2 at 2.2 feet bgs) contain the highest LNAPL conductivities. These are the coarser of the samples according to the laboratory grain-size analysis (Table 6-4), so with all other things considered equal, it would be expected that the coarser samples would exhibit the highest potential to transmit fluids. However, as explained above, even the maximum LNAPL conductivity calculated (8.32×10^{-7} cm/sec) is still lower than the design standard hydraulic conductivity for groundwater leachate through a hazardous waste liner (1×10^{-6} cm/sec).

The primary reason for the LNAPL conductivities being so low can likely be attributed to the LNAPL viscosity, which is a key parameter in the LNAPL conductivity equation. The laboratory-measured viscosity of the LNAPL sample collected from PZ-7 (the LNAPL used to represent the product found at the site) was 226 centipoise at a temperature of 70 degrees Fahrenheit. Using this along with the viscosity values measured by the laboratory at 100 and 130 degrees Fahrenheit, the LNAPL viscosity was extrapolated to a reasonable in-situ site temperature of 50 degrees Fahrenheit, resulting in an LNAPL viscosity of 271 centipoise. For comparison, the water from the site was measured to have a viscosity of approximately 1.2 centipoise (extrapolated to 50 degrees Fahrenheit); a typical gasoline product has a viscosity of approximately 0.4 to 0.5 centipoise. Therefore, the resultant LNAPL conductivities presented in Table 6-4 are not unexpected and confirms that high viscosity fluids at ambient site temperatures tend to not be mobile.

6.3.1.3 Potential LNAPL Mobility

The above analysis uses site-specific data to calculate an in situ LNAPL conductivity, and this value may be used to calculate an LNAPL pore velocity using a modified form of Darcy's Law. However, in order to understand the true potential for LNAPL to migrate in site soils, residual LNAPL saturation threshold and LNAPL gradients must also be evaluated.

Residual LNAPL Saturation Threshold

Residual LNAPL saturation threshold is an important parameter to understand because in theory LNAPL will not migrate if it is present at concentrations below the residual LNAPL saturation threshold. The residual LNAPL saturation threshold is defined as the saturation of LNAPL below which LNAPL is present only as disconnected globules and will not migrate under any gradient because of physical constraints resulting from the disconnected nature of the LNAPL globules, and the presence of trapped water and air within the same pore space.

Free-product mobility (FPM) tests were performed on multiple soil samples (one from each of the capillary pressure LIF locations) to better understand the potential for LNAPL mobility and the gradients required to mobilize it. Sub-samples were collected by the laboratory from the soil cores as close to the locations tested for DCP testing as possible. In some cases, the FPM sample location had to be displaced vertically (within the soil core) from the location of the corresponding DCPT sample because previous sample analyses consumed the soil from the depth of interval of primary interest.

The FPM tests were run in a centrifuge by the laboratory. The centrifuge speed used for each test was designed to simulate worst case pressure gradient conditions (1,000 times gravity as dictated by the American Society for Testing Materials method) within the subsurface. Table 6-5 summarizes the FPM test results.

As shown in Table 6-5, only the silt sample from 10.7 feet bgs at LIF-PZ7-09-13-2 contained sufficient LNAPL to induce LNAPL mobility during the test (initial LNAPL saturation of 17.1

percent and residual saturation of 12.9 percent). The test results indicate that for the other samples, the residual LNAPL saturations were greater than the initial LNAPL saturations.

The resultant 12.9 percent residual LNAPL saturation in the sample from LIF-PZ7-09-13-2 at 10.7 feet bgs indicates that LNAPL detected at that location exists at saturations above residual and thus has the potential to be mobile. Because the other samples all contained initial saturations below residual levels, no conclusions can be drawn regarding the potential mobility of LNAPL found at those locations. It can be assumed, however, that the residual LNAPL saturation of the coarser-grained sediments found at locations LIF-040-00-05-2 and LIF-032-01-05-2 would be lower than the residual LNAPL saturation for the silt sample at LIF-PZ7-09-13-2 (12.9 percent). As indicated in Section 6.3.1.2, even with measured LNAPL saturations significantly above residual levels, the LNAPL observed at the site is estimated to have a potential mobility lower than that allowed for groundwater leachate through a hazardous waste landfill liner.

LNAPL Pore Velocity

Additional calculations were performed to estimate the distance the LNAPL could migrate under induced gradients. A significant number of the soil samples tested exhibited high LNAPL saturations that likely are greater than the residual LNAPL saturation thresholds. Additionally the FPM tests indicated some potential mobility within a sample with an initial LNAPL saturation as low (relative to other measured LNAPL saturations) as 17.1 percent. The LNAPL pore velocity (PV_{NAPL}) was calculated from:

$$PV_{NAPL} = \frac{(K_{NAPL} * i)}{(\theta * S_{NAPL})}$$

where K_{NAPL} is the LNAPL conductivity (cm/sec), i is the LNAPL gradient, θ is the total porosity, and S_{NAPL} is the LNAPL saturation.

The LNAPL pore velocity can be calculated for any LNAPL saturation. Because the LNAPL saturation varies within the zone of potentially mobile LNAPL from zero at the LNAPL/water interface to a maximum value near the LNAPL/air interface, the pore velocity also varies from zero at the LNAPL/water interface to a maximum value near the LNAPL/air interface. In other words, LNAPL within the smear zone can move at different rates at the top and bottom of the smear zone. The difference in rate, however, is typically not significant. Therefore, to be conservative for this analysis, the LNAPL pore velocity for the maximum LNAPL saturation (using the refined curve fit parameter analysis) was chosen to evaluate the potential for LNAPL movement.

The site-wide average LNAPL gradient was conservatively assumed to be 0.01 based on using a typical value for groundwater hydraulic gradients. Hydraulic gradients are usually greater than hydrocarbon gradients, specifically in the case of older fuel releases. It is expected that since the Diamond Head Oil refinery operations stopped in 1979, LNAPL gradients have diminished and currently are minimal. The total porosity values were selected from the laboratory tests of the individual soil samples. The maximum LNAPL pore velocity estimation results are presented in Table 6-6.

Table 6-6 shows that the results are in agreement with the expectation that LNAPL at the Diamond Head Oil Superfund site is not mobile. As described above, this is more related to the high viscosity of the LNAPL than the saturations found in the soil. The estimated LNAPL pore velocity ranged from a high of 1.15×10^{-7} cm/sec (about 0.1 foot per year) in the fine

sand in LIF-032-01-05-2 to a low of 3.7×10^{-9} cm/sec (about 0.004 foot per year) in the silt in LIF-PZ7-09-13-2 and the fine sand in LIF-005-08-15-2.

It should be noted that these LNAPL pore velocity estimates are conservative, pin-point, and snapshot in-time estimates and do not indicate bulk LNAPL mobility at the leading edge of the LNAPL plume. As LNAPL migrates, it tends to smear reducing the migration velocity. As a result mobility progressively decreases at the leading edge of a plume. Additionally, the calculations presented here do not account for the effects of residual LNAPL saturation, which act to limit mobility up to the threshold value. This is an important consideration since, as was observed for the silt sample from LIF-PZ7-09-13-2 at a depth of 10.7 feet bgs, LNAPL is likely immobile for saturations up to about 13 percent, and at saturations probably between about 5 and 10 percent for the other coarser-sediment locations. Because the effects of the residual LNAPL saturation threshold were ignored during the calculation of pore velocity estimates, the results are conservative, and likely overestimate potential LNAPL mobility at the site. Regardless, the results of the LNAPL mobility investigation indicate that the LNAPL is generally not mobile at the Diamond Head Oil Superfund site and would not be expected to migrate great distances from its source and/or present location.

6.3.2 LNAPL Recoverability Assessment

Following the LNAPL mobility assessment, a simplified LNAPL recoverability model was run to assess the potential to recover the LNAPL found at the site. Results of the recoverability assessment are described in this section.

6.3.2.1 LNAPL Recovery Model

The model used to assess the recoverability of the site LNAPL was the LNAPL Distribution and Recovery Model (LDRM) published by the American Petroleum Institute (API) in API's Publication Number 4760 dated January 2007 (API, 2007). The recovery portion of LDRM uses fluid and soil parameters (such as those described in the preceding sections of this report) to estimate a production rate for various LNAPL remediation scenarios. For the Diamond Head Oil Superfund site recoverability assessment, the model was used to evaluate the potential recovery of LNAPL using an LNAPL skimming well at each of the four locations sampled for the mobility assessment. Details regarding the applicable equations used in the LNAPL recovery model can be found in API, 2007 and will not be described further in this document.

6.3.2.2 Recovery Model Parameters

The parameters generated for the LNAPL mobility assessment, including the fluid properties from the LNAPL in piezometer PZ-7, were used in the recovery model. For the soil parameters, the values generated from the refined curve fit were used. The recovery model parameters are summarized in Tables 6-7 (fluid parameters) and 6-8 (soil/location parameters).

In addition to the fluid and soil/location parameters listed above, the recovery model was run using the following scenario:

- LNAPL skimming well (zero water production or vacuum-induced pressure gradients)
- Design recovery time – 30 years
- Radius of well – 0.167 foot (*i.e.*, a 4-inch diameter well)

- Radius of capture – 10 feet
- Radius of influence – 10 feet

6.3.2.3 Recovery Model Results

Based on the parameters described above, the API LDRM model was run for each location to determine a total LNAPL production volume and percent total recovery based on a model-calculated initial volume. The model calculates an initial volume based on the input parameters and an assumed radius of capture (cylinder with which the LNAPL resides). The recovery model results, based on 30 years of operation, are summarized in Table 6-9. The complete recovery model output files are included in Appendix 5.

The recovery model results shown in Table 6-9 are consistent with the LNAPL mobility assessment. That is, the LNAPL found at the Diamond Head Oil Superfund site has very limited mobility and is, for the most part, not practicably recoverable. This is further demonstrated by the low Percent Recovery values (0.52% to 6.6%) that are shown in Table 6-9 which describe the percent recovery of the estimated total LNAPL mass contained within the radius of influence (assumed to be 10-feet) of the skimming well that would likely be recovered after operating a remediation system for 30 years.

6.4 Summary of LNAPL Mobility and Recoverability Assessment

An LNAPL mobility and recoverability assessment was performed using the results of laboratory testing on four soil samples and one LNAPL sample from the Diamond Head Oil Superfund site. The results presented in Section 6.3.1 (LNAPL Mobility Assessment) and 6.3.2 (LNAPL Recoverability Assessment) are consistent in that both evaluations conclude that the LNAPL found at the site is relatively immobile and not recoverable.

6.4.1 LNAPL Conductivity

Results from the LNAPL mobility assessment showed that the two shallow samples (LIF-040-00-05-2 at 0.8 foot bgs and LIF-032-01-05-2 at 2.2 feet bgs) demonstrated the highest LNAPL conductivities. According to the laboratory grain-size analysis, these samples contained the coarsest sediments and would therefore be expected to exhibit the highest potential to transmit fluids. However, the maximum LNAPL conductivity calculated (8.3×10^{-7} cm/sec) is lower than the design standard hydraulic conductivity for a hazardous waste landfill liner (1×10^{-6} cm/sec), indicating that at its most transmissive, the high viscosity of the LNAPL (estimated at 271 centipoise at a temperature of 50 degrees Fahrenheit, roughly 2 orders of magnitude higher than the site water), inhibits its mobility.

6.4.2 Residual LNAPL Saturation Threshold

The LNAPL residual saturation test performed by the laboratory provided little benefit due to a combination of the relatively low initial LNAPL saturations and the high LNAPL residual saturations for the soils sampled. Of the four tests conducted, only the silt sample from a depth of 10.7 feet bgs at LIF-PZ7-09-13-2 provided a true laboratory value of LNAPL residual saturation (12.9 percent). The test results indicated that for the other three samples, the residual LNAPL saturations were greater than the initial LNAPL saturations.

The LNAPL residual saturation of 12.9 percent in the sample from LIF-PZ7-09-13-2 at 10.7 feet bgs indicates that (based on the PFS results) LNAPL exists at saturations above residual and thus has the potential to be mobile. Because the other samples all contained initial saturations below residual levels, no further conclusions could be drawn regarding the potential mobility of LNAPL found at those locations. Due to the coarser nature of the sediments found at locations LIF-040-00-05-2 and LIF-032-01-05-2, it is presumed that the residual LNAPL saturations at those locations would be lower than 12.9 percent, meaning that (based on the PFS results) LNAPL detected at those locations exists at saturations significantly above residual and thus also has the potential to be mobile. However, as indicated from the LNAPL mobility analysis, even with the elevated LNAPL saturation, none of these samples have LNAPL conductivities greater than about 1×10^{-7} cm/sec.

6.4.3 LNAPL Pore Velocity

Consistent with the LNAPL conductivities results of the LNAPL pore velocity calculations showed that the estimated velocity of the LNAPL ranged from about 0.004 foot/year up to a maximum of only about 0.1 foot per year. These results were based on an assumed LNAPL gradient of 0.01, which is conservatively high based on the age of the release. In addition, the LNAPL pore velocity calculations performed for the mobility assessment did not account for the effects of residual LNAPL saturation, which would further limit the mobility up to the threshold value. As was observed for the silt sample from LIF-PZ7-09-13-2, LNAPL is likely immobile for saturations up to about 13 percent at that location, and at saturations probably between about 5 and 10 percent for the other coarser-sediment locations. Because the effects of the residual LNAPL saturation threshold were ignored during the calculation of pore velocity estimates, the results are conservative, and likely overestimate potential LNAPL mobility at the site.

6.4.4 LNAPL Recoverability Assessment

Simplified recovery modeling of the LNAPL at the site, using the fluid and soil parameters generated by the laboratory and the mobility assessment, indicated that the LNAPL at the site is generally not recoverable. Results of the recovery modeling over a time period of 30 years showed that at most, approximately 5 to 6 percent of the initial volume of LNAPL could be recovered. Furthermore, the recovery modeling did not account for the residual LNAPL saturation threshold and therefore, the model overestimates the total recovery of LNAPL from the four locations tested.

In addition to the above conclusions, soil core analysis (visual inspection, core photography, PFS analysis, and DCP testing) indicated that soil conditions in the areas and at depths where the LNAPL plume is present are extremely heterogeneous. This condition leads to significant variation in potential LNAPL mobility over relatively small vertical and lateral distances across the site. Soil types ranged from silt to medium sand across the area that was sampled for this evaluation.

The results of the LNAPL mobility and recoverability assessment must be interpreted within the context of the assumptions used for the calculations. However, all practical effort was made to present conservative parameter values so that the result may possibly be an overestimate of the potential mobility and recovery of the LNAPL.

SECTION 7

Pilot Test—Air/Bio Sparge

Section 7 describes the following:

1. The purpose and scope of the air/bio sparge pilot test
2. Implementation of the air/bio sparge pilot test, including:
 - Obtaining relevant NJDEP permits for air emissions from system and discharge of water from trench construction
 - Construction of the horizontal sparge trench
 - Installation of temporary piezometers for monitoring the performance of the system
 - Performing the pilot test
 - Monitoring of field parameters before, during, and after the test
 - Groundwater sampling to document baseline conditions and assess the effects of the technology
3. Results of the pilot test, evaluating the operational and treatment effectiveness of the technology for addressing LNAPL contamination

7.1 Purpose and Scope

The purpose of the pilot air/bio sparge test was to provide data that can be used to evaluate the applicability and effectiveness of the air/bio sparge technology for the bioremediation of residual LNAPL. During the work planning phase of the project, the air/bio sparge technology was identified as one technology that could be used to reduce residual LNAPL contamination in the unsaturated and saturated zones in the subsurface. The process of sparging (i.e., injecting) air into the subsurface can both remove petroleum compounds through volatilization, as well as promote the biodegradation of the petroleum compounds by increasing the concentration of oxygen in the soil and groundwater and stimulating the activity and growth of the natural bacterial populations.

Implementation of the pilot test was designed to evaluate site conditions with respect to naturally occurring bacteria and the viability of the sparging technology to enhance the natural biological activity. Additionally, the pilot test was designed to provide information that could assist in developing full-scale design specifications for criteria, including well spacing, injection rates, and injection depths. The pilot test also included an assessment of the radius of influence that can be achieved by an air/bio sparge system at the Diamond Head site. Limited groundwater sampling (screening level data) was collected to assess this technology.

Given the shallow depth to water and the depth to the semi-confining low permeability layer beneath the site (peat), the test was conducted using a horizontal sparge well. Vertical sparge points in the geologic conditions present at the site were expected to have a small radius of influence, resulting in a very large number of sparge points for the needed areal coverage. Horizontal sparge wells are expected to be more effective at oxygen delivery and less costly.

7.2 Implementation of Air/Bio Sparge Test

7.2.1 Permits

Prior to mobilizing to the field, the applicability of permitting regulations was discussed with USEPA and NJDEP. Two permitting requirements were identified, and documentation in support of obtaining these permits was assembled and submitted to NJDEP.

The first was a permit-by-rule under the New Jersey Pollutant Discharge Elimination System/Discharge to Groundwater (NJPDES/DGW) Permit-by-Rule process. This permit allowed the discharge of groundwater to the ground surface while dewatering the trench during its excavation, and construction of the horizontal air sparge well.

The second was an Environmental Improvement Pilot Test (EIPT) approval obtained through the NJDEP's Division of Air Quality. This approval—in accordance with N.J.A.C. 7:27-8.9(e)—was for potential air emissions from the operation of the air injection equipment.

All monitoring and reporting requirements were implemented in accordance with the stipulations in the two approvals.

7.2.2 Construction of Test Trench

The air/bio sparge trench was constructed between February 19, 2008, and February 21, 2008, by Lewis Environmental utilizing a Caterpillar 321C hydraulic excavator. The location of the completed air/bio sparge trench, near monitoring well MW-11s, is shown in Figure 1-2. The actual location where the trench was constructed is different from the location where the trench was planned during project work planning. The causes for moving the trench are described below.

In order to evaluate the equipment that would be needed to dewater the trench during its construction, a test pit was constructed on January 28, 2008, by Lewis Environmental. The test pit was constructed adjacent to the planned trench location—20 feet southeast of piezometer PZ-16. During test pit excavation, a large concrete slab was encountered at approximately 6 feet bgs. Excavation was terminated upon contacting the concrete slab and groundwater was allowed to flow into the open pit. In addition to groundwater infiltration, isolated seeps of LNAPL were observed entering the test pit from the walls of the test pit at the water table elevation. The excavated test pit was backfilled with the native spoils and compacted using the excavator bucket. CH2M HILL determined that the planned trench location in the area of PZ-16 was compromised because of the presence of the large concrete slab.

After evaluating subsurface lithology and analytical soil and groundwater results from the Phase 1 RI, an alternative location for the air/bio sparge trench was selected between monitoring wells MW-11S and MW-11D. A second test pit was excavated in the newly selected location, and subsurface conditions were determined to be conducive for the air/bio sparge pilot. During the excavation of the full-size pilot trench at this location, however, the excavation wall collapsed and a third location needed to be selected approximately 20 feet southeast of MW-11S. The pilot test trench was successfully constructed at this location, as shown in Figure 1-3.

The pilot test location is not in an area where free-phase LNAPL has been historically observed. LIF data from nearby locations (LIF-012, LIF-031, LIF-035, see also Figure 1-2)

do indicate, however, the potential for LNAPL to be present in the area, and sheens were observed on the water during construction of the trench. This information, in addition to the proximity to the former sludge lagoon area (150 feet away), suggests it is possible that free-phase or residual LNAPL may be present in the area of the air/bio sparge trench.

The lithology of the excavated soil at this location was documented by a geologist and screened with a PID. A description of the subsurface soil observed during the excavation is included in the cross section of the air sparge trench provided in Appendix 6. The general subsurface lithology was observed to consist of the following:

- A surficial layer of poorly sorted sand and gravel containing refuse and debris from ground surface to 7 feet bgs
- A moderately stiff sandy-clay layer extending from 7 feet bgs to an inferred depth (according to Phase 1 boring logs) of 13.5 feet bgs (the excavation was terminated at 10 feet bgs)

In order to achieve the maximum radius of influence, the air/bio sparge system and accompanying temporary piezometers were installed in the upper sand and gravel layer (8 feet deep) on top of the underlying confining clay layer.

The pilot test trench was constructed with the following dimensions: 32 feet long, 3.5 feet wide, and 8 feet deep. During construction, the excavation was dewatered utilizing a 4-inch pump with a maximum pumping rate of 500 gallons per minute. Groundwater was pumped from the open trench excavation and discharged approximately 150 feet southwest into the footprint of the former sludge lagoon area, that was already inundated with standing water. Prior to discharging, the entire sludge lagoon area was surrounded with hay bales to prevent the water from flooding surrounding areas. In addition, the water was discharged through a diffusion device consisting of an anchored 55-gallon drum with rip-rap boulders to dissipate the energy of the water.

A steel trench box measuring 8 feet high by 12 feet long and 3 feet wide was used to prevent the side walls from becoming unstable and unsafe during installation of the air sparge piping. Prior to constructing the air sparge piping system, 12 inches of certified clean silica sand (FilPro #2 sand, clean certification provided in Appendix 6) was installed at the base of the excavation. A 30-foot-long horizontal screen consisting of 2-inch-diameter, schedule 80 polyvinyl chloride (PVC) with 0.02-inch (20-slot) slotted screen was installed at the bottom of the trench resting on the bed of silica sand. The pipe invert is located at 7 feet below grade. Solid riser pipe of 2-inch schedule 80 PVC was connected to both ends of the horizontal screen using right-angle connectors to form vertical riser pipes that were completed above grade for connection to the air sparge system.

Additional filter sand (FilPro #2) was then added to the air sparge trench to encase the entire length of the 30-foot-long air sparge screen. An additional 6-inch layer of sand was installed on top of the horizontal screen to help prevent the screen from clogging with formation silt. A 6-inch-thick layer of 3/8-inch bentonite clay chips was placed on top of the sand layer and hydrated to create a seal on the excavation below the water table and prevent short-circuiting or preferential flow of air directly upward through the excavated soils. The air/bio sparge trench was immediately backfilled with native soil and compacted with the excavator bucket. Figure 7-1 contains a cross-sectional view of the constructed trench, and additional trench detail is provided in Appendix 6, including an excavation log.

Dust control was not required because of the intrinsic moisture content of the excavated soil. During the excavation activities, spoils were temporarily staged on poly sheeting before being backfilled into the trench.

Survey information of the air/bio sparge piping was collected by Lewis Environmental at the north side of each riser stick-up pipe. Lewis Environmental utilized a Trimble GPS 5800 RTK Rover with an internal 450-470 megahertz (MHz) radio to an accuracy of 0.25 meter to collect the spatial information. All coordinates were recorded using the New Jersey State Plane, NAD 1983 system.

CH2M HILL utilized transit level and stadia rod techniques on March 26, 2008, to measure the elevations at each of the vertical air/bio sparge riser pipes. Elevation data collected at MW-12S during the Phase 1 RI was used as a benchmark while using the transit and stadia rod survey technique. Surveyed data were collected to an accuracy of 0.01 foot at the top of each PVC stick-up.

The horizontal and vertical survey data for the air/bio sparge trench is provided in Appendix 6.

7.2.3 Installation of Temporary Piezometers

In order to evaluate the effectiveness and radial influence of the air/bio sparge system, five temporary piezometer wells were installed at varying distances on each side of the horizontal air/bio sparge trench. All five piezometers were installed on March 20, 2008, by EPI using a truck-mounted Geoprobe® 5410 equipped with direct push technology (DPT). Each piezometer was set and screened within the upper sand and gravel layer with a screen from 2 to 7 feet bgs. Temporary piezometers were constructed using 1-inch-diameter, schedule 40 PVC with 0.01-inch (10-slot)-slotted screen and 1-inch, schedule 40 PVC riser. Certified clean silica sand (FilPro #2) was installed around the entire length of screen up to a depth of 1 foot bgs (clean certification provided in Appendix 4). A hydrated bentonite seal was added from the top of the sand pack to ground surface. Well construction diagrams are provided in Appendix 6.

Figure 1-2 shows the location of the temporary piezometers. Two piezometers (PZ-AS-01, PZ-AS-05) were installed 5 feet away from the air/bio sparge piping, two piezometers (PZ-AS-02, PZ-AS-04) were installed 10 feet away, and PZ-AS-03 was installed 15 feet away. Existing monitoring well MW-11S, located 20 feet from the air/bio sparge piping, was also monitored during the pilot test. The table below summarizes the information on the used sampling points.

Sampling Point Identification	Distance of Sampling Point from Air/Bio Sparge Piping (feet)	Screened Interval (feet bgs)
PZ-AS-01	5	2-7
PZ-AS-02	10	2-7
PZ-AS-03	15	2-7
PZ-AS-04	10	2-7
PZ-AS-05	5	2-7
MW-11S	20	2-12

All temporary piezometers were allowed to equilibrate with the surrounding aquifer for a period of 17 days prior to baseline sampling. Upon completion of the air/bio sparge pilot test, the temporary piezometers were decommissioned in accordance with NJDEP guidelines.

Spatial and elevation information were recorded by CH2M HILL at each of the five temporary piezometers as outlined in Section 7.2.2. The survey information for each of the temporary piezometers is presented in Appendix 6.

7.2.4 Implementation of Air/Bio Sparge Pilot Test

Implementation of the pilot test consisted of connecting the equipment to the easternmost riser pipe in the trench, capping the western riser pipe, collecting one round of groundwater samples to determine baseline groundwater conditions, operating and monitoring the system for a period of 2 weeks, and collecting a round of groundwater samples at the end of the 2-week-period to evaluate post-test groundwater conditions. These are described below.

7.2.4.1 Equipment Installation

A trailer-mounted air/bio sparge rental system was delivered to the site by Maple Leaf Environmental Equipment on March, 7, 2008. The equipment consisted of a rotary claw sparge compressor, a heat exchanger, and a 2-inch-diameter manifold. At full operating capacity, the system could deliver a flow of 30 standard cubic feet per minute (scfm) at 20 pounds per square inch (psi) pressure.

A 2-inch-diameter pressure hose was used to connect the sparge manifold to the eastern air/bio sparge riser pipe. The western riser pipe was terminated with a cap. The manifold included a flow indicator, pressure indicator, and gate valve to adjust air flow.

A New Jersey State licensed electrician from Northern Electric Co. was onsite the morning of March 7, 2008, to connect the air/bio sparge equipment to a rental 230-Volt, 3-phase generator. After the electrical components and blower motor direction were tested, all sparge connections were temporarily pressure tested, and the sparge system was disconnected and performance tested. Performance test results were recorded in the field logbook.

7.2.4.2 Baseline (Pre-Pilot) Monitoring

Baseline (pre-pilot) monitoring data for the air/bio sparge was collected from five temporary piezometers (PZ-AS-01, PZ-AS-02, PZ-AS-03, PZ-AS-04, PZ-AS-05) and MW-11S. MW-11S was included in the air/bio pilot test as a monitoring point because of its shallow screen interval and proximity (approximately 20 feet) to the air/bio sparge injection pipe. A summary of analytical sample information is included in Table 3-1.

Baseline groundwater samples were collected between March 7 and March 8, 2008, using low-flow sampling procedures from each monitoring point with a peristaltic pump and dedicated tubing set at a depth corresponding to 6 inches from the bottom of the piezometer, except at MW-11S. At this well, the sample was collected at a depth within the screen interval corresponding to the depths at which the samples were collected within the piezometers. Because of the narrow diameter of the temporary well points and the inability to get a bailer into the temporary casing, the samples were collected directly from the peristaltic pump discharge. Low flow sampling logs are included in Appendix 6.

The samples were sent for analysis for TCL-VOCs through the CLP program. Because the data were used for screening purposes, no quality control samples other than an equipment blank and a trip blank were included with the sample set. All TCL-VOC samples received through CLP were validated through USEPA. Validation included the review of data to assess accuracy, precision, and completeness using the following standard procedures:

- Organic compounds: USEPA Region II Data Validation SOP for Statement of Work OLM04.2 (SOP HW-6 [revision 12] March 2001)

No issues were noted with the data and the following data qualifiers were added to the data when the QA/QC data indicated a bias:

- U The material was analyzed for but was not detected above the level of the associated value. The associated value is either the sample quantitation limit or the sample detection limit/
- J The associated value is an estimated quantity. Used when the data indicated the presence of a component was below the stated reporting limit or when the direction of analytical bias was unknown.
- UJ The component was analyzed for but not detected at a level equal to or greater than the reporting limit. Used when QA/QC data indicated a bias in the analytical data but the direction of bias is unknown.

A full discussion of data qualifications is available with the data packages. The data packages are not included in this report because of their volume, but are kept in the project files.

In addition to TCL-VOC analysis, groundwater samples were collected from the same set of monitoring wells and piezometers and sent overnight to Microbial Insights for phospholipid fatty acid (PLFA) analysis.

Additional groundwater quality field parameters were collected from the five temporary piezometers and monitoring well MW-11S for baseline groundwater chemistry monitoring. The following parameters were collected and recorded in field data sheets: depth to groundwater, dissolved oxygen (DO), oxidation reduction potential (ORP), conductivity, pH, and temperature. Results of the baseline and daily groundwater monitoring parameters are presented in Table 1 in Appendix 6.

7.2.4.3 Air Sparge Operation

Air/bio sparge pilot testing was performed between March 8 and March 18, 2008, and was conducted generally following the step-rate testing procedures outlined in the *In situ Air Sparging Engineering and Design Manual* (USACE, 1997). During this time, the air/bio sparge system was operated continuously to deliver air to the shallow sand and gravel layer. The air injection timetable and injection parameters are summarized in Table 2 in Appendix 6.

The air/bio sparge test was initiated by injecting air at a flow rate of 8 scfm at the eastern riser pipe connection. This corresponds to approximately 0.3 scfm per foot of well screen. The injection pressure (up to 2.8 psi) was closely monitored during this time so that the injected pressure did not exceed the pressure that could create pneumatic fracturing of the subsurface (approximately 5 psi).

After an initial injection period of approximately 12 hours, system parameters, flow rates, and pressure were recorded. Data are presented in Table 2 in Appendix 6.

Each morning, a full round of groundwater and vapor measurements were collected from the five temporary piezometers and monitoring well MW-11S. Daily recorded parameters, presented in Tables 1 and 3 in Appendix 6, included:

- Water levels measured from the top of well casing to the water level surface.
- Groundwater field parameters (DO, temperature, pH, specific conductivity, and ORP).
- Wellhead vapor pressure with a digital manometer.
- Vapor concentrations monitored for VOCs with a PID and percent oxygen, carbon dioxide (CO₂), CH₄, and LEL with a landfill gas sampler. Vapor samples were first collected using a vacuum pump with Tedlar® bags, and the Tedlar® bags were then connected to a PID and landfill gas sampler to obtain these readings.

Air flow rates were increased throughout the duration of the pilot test to achieve approximate injection rates of 18, 24, and 30 scfm (0.6, 0.8, and 1.0 scfm/foot well screen). Groundwater and vapor parameters were collected the following morning after each flow rate increase to allow adequate time for subsurface conditions to stabilize.

Details of air sparge operation flow rates, pressure, run time, etc., are included in Table 2 in Appendix 6. The air/bio sparge system ran continuously throughout the test, with the exception of a preventive automatic system shutdown caused by high operating temperatures inside the trailer. This shutdown occurred some time between April 12 and the morning of April 14, 2008. The exact date and time of this shutdown is unknown since the system was not monitored over the weekend. The system was restarted on April 14, 2008, modifications were made to the enclosed trailer to provide additional ventilation, and the system operated continuously until the end of the pilot test on April 18, 2008.

7.2.4.4 Post-Pilot Monitoring

Immediately following system shutdown on April 18, 2008, post-pilot groundwater samples were collected from the five temporary piezometers and MW-11S following the same procedures that were followed during the pre-pilot baseline monitoring. The groundwater samples were also sent for the same analyses as the pre-pilot samples (TCL-VOCs and PLFA) so the data could be used to assess changes in VOC concentrations and bacterial activity as a result of air/bio sparging. The low flow sampling logs are included in Appendix 6.

Upon completion of the pilot test, the air sparge system was decommissioned by CH2M HILL and demobilized from the site by Maple Leaf Environmental Equipment.

7.3 Results of Air/Bio Sparge Test

Field parameters collected during the air/bio sparge pilot test are summarized in Tables 1 and 3 in Appendix 6. Specifically, groundwater parameters including depth to groundwater, DO, ORP, conductivity, pH, and temperature are presented in Table 1, vapor data including percent oxygen, CO₂, CH₄, and LEL are presented in Table 3. Analytical results from VOC and PLFA analyses are presented in Tables 6-1 and 6-2, respectively. The complete VOC results are presented in Table 4 in Appendix 6.

The results of the air/bio sparge pilot test are discussed below in terms of physical, geochemical, and biological indicators.

7.3.1 Physical Indicators

The effects of air/bio sparge on the subsurface were immediately observed following commencement of the pilot test. Upon system startup, air bubbles were produced in standing water at the ground surface in an approximate 5-foot-radius surrounding the air/bio sparge trench. As the pilot test progressed and flow rates were increased, a significant increase in surface air bubbles occurred originating in all directions surrounding the air/bio sparge trench. At 18 scfm, air bubbles were witnessed in several isolated areas approximately 20 feet away from both sides of the air/bio sparge trench. Field screening with a PID was conducted at the ground surface where bubbles were observed. The results showed the presence of VOCs in vapors at the ground surface at concentrations up to 40 ppm during the test. At a height of 12 inches above ground surface, however, VOCs were not detected with the PID during the test. The presence of VOCs in ground surface vapors suggests stripping of VOCs from the soil and groundwater and into soil vapor near the trench, and that these concentrations are quickly attenuated within 1 foot above ground surface.

The introduction of air into the subsurface generally created and maintained positive pressure at each sampling point throughout the pilot test, as shown in Table 3 in Appendix 6. At piezometer PZ-AS-01, located 5 feet from the injection pipe, a mixture of water and air bubbled over the top of the well casing during sparging. Occasionally, the same occurrence was observed at PZ-AS-04 located 10 feet from the injection pipe. These wells were capped when they were not being sampled to minimize short-circuiting to the atmosphere and promote subsurface air flow. Positive pressures at the sample points suggest that air/bio sparge was influencing the subsurface over an approximately 20-foot-distance from the air/bio sparge injection pipe. Although pressure readings were variable at times, positive pressures appeared to be highest at points closest to the air/bio sparge trench and decreased away from the trench.

Field vapor parameters collected throughout the pilot test also suggest that injected air was influencing the saturated zone at each sampling point. Oxygen concentrations in vapor accumulating in the well casings (note that the screened section of all monitoring wells and piezometers was submerged) were similar to ambient air concentrations (over 20 percent oxygen), showing little increase or decrease throughout the test. In comparison, PZ-18, located outside of the pilot test area, produced sustained low concentrations of oxygen in well headspace throughout the test, indicating this well was not influenced by the air/bio sparge system.

Fluctuations in the groundwater level were apparent during the test, although a slight increase in average depth to water measurements (decrease in groundwater elevation) was observed between the start and finish of the pilot test. Water levels were likely affected by the air/bio sparge test, but the frequency of water level measurements was not high enough to capture the mounding, stabilization, and collapse that is typically observed during most air sparge tests.

An increase in groundwater temperature was noticed throughout the pilot test. This increase is possibly because of the air/bio sparge system operation. Air injected into the subsurface was injected at an average temperature of 28 degrees Celsius (83 degrees Fahrenheit). Subsequently, an increase in groundwater temperature was noticed in the monitored piezometers over the course of the pilot test. Groundwater temperatures

increased from an average temperature of 9.37 degrees Celsius (49 degrees Fahrenheit) to 11.3 degrees Celsius (52 degrees Fahrenheit) at the conclusion of the test, creating a more favorable environment for bacteria growth.

7.3.2 Geochemical Indicators

Average DO values increased shortly after startup of the air/bio sparge system. The DO concentrations remained elevated throughout the pilot test, and decreased shortly after the pilot test was shut down. Some wells (PZ-AS-01, PZ-AS-02, and PZ-AS-04) required relatively low air flow rates (less than 0.4 scfm/foot of horizontal screen) to have an influence on DO, while other wells (PZ-AS-03, PZ-AS-05, and MW-11s) required higher flow rates (greater than 0.6 scfm/foot) to show DO influence. ORP also showed a general increase over the course of the pilot test. Baseline groundwater parameters of negative ORP values were recorded at each sampling point, except MW-11S.

Monitoring Location	Baseline Pre-Pilot DO Concentrations (mg/L)	Average DO During Pilot Test (mg/L)	Post-Pilot DO Concentrations (mg/L)
PZ-AS-01	0.29	7.73	3.11
PZ-AS-02	0.99	2.44	0.85
PZ-AS-03	1.08	2.88	0.37
PZ-AS-04	0.37	2.87	2.25
PZ-AS-05	0.39	2.15	1.3
MW-11S	0.82	1.37	1.31

Note that on April 12, 2008, a precipitation event of 0.67 inch occurred in the vicinity of the site. This rainwater would have high DO concentrations (near saturation) and could have influenced DO readings at the site, particularly at PZ-AS-03, PZ-AS-04, PZ-AS-05, and MW-11Ss. This event also could have influenced depth to water and water temperature.

In general, the DO and ORP results suggest the following:

- A reduced anaerobic environment existed in the subsurface prior to the pilot test.
- Air/bio sparge was effective in delivering oxygen and, thereby, promoting aerobic conditions in the subsurface. A general trend toward an aerobic environment was observed during the pilot test and at the conclusion of the test, aerobic conditions remained present at PZ-AS-03, PZ-AS-04, PZ-AS-05, and MW-11S for 2 to 4 hours after the test.
- Biochemical activity in the subsurface is expected to utilize oxygen rapidly to degrade petroleum hydrocarbons and other organics present in the subsurface.

The pH in groundwater was elevated prior to the start of the air/bio sparge test and remained unaffected over its duration. The pH was generally over 12, and this may adversely affect bacterial growth in the subsurface. Additional bench tests may be appropriate to determine the effect of pH on bacterial growth at the site.

Summaries of the analytical data are presented in Table 6-1. Only samples that contained detectable analyte concentrations are included in this table. Complete analytical results for all samples can be found in Table 4 in Appendix 6.

Overall, VOC concentrations showed no significant change between baseline (pre-pilot) and post-pilot samples. Acetone was detected in trip and equipment blank QC samples, making any conclusions in acetone concentrations unreliable.

A slight decrease in VOC concentrations in PZ-AS-01 (one of the two piezometers closest to the test trench) was noticed, possibly caused by the physical air stripping effects created by the air/bio sparge system. Slight increases in toluene and xylenes occurred in PZ-AS-2, PZ-AS-3, and PZ-AS-5 and no significant changes in VOC concentrations were observed in PZ-AS-04.

Increases in VOC concentrations observed during the pilot test may be caused by the mobilization of the VOCs from the soil to the water matrix created by sparging. Specifically, the physical act of sparging air into the subsurface may have desorbed VOCs and residual LNAPL from the soil into the groundwater and the vapors that were monitored during the test. Elevated PID readings collected during the pilot test suggest that VOCs were in fact partitioning into vapor during the pilot test. The length of the sparge test may have been insufficient to strip VOCs from groundwater to the point that lower VOC concentrations were observed in groundwater; more operation time may have resulted in improved groundwater treatment through stripping mechanisms.

In the anaerobic conditions in the subsurface prior to the start of the pilot test, reductive dechlorination of CVOCs was likely naturally occurring in the groundwater. This process includes the sequential removal of chlorine molecules from parent compounds (tetrachloroethene or trichloroethene) to trichloroethene, cis-1,2-dichloroethene (c-1,2-DCE), vinyl chloride (VC), and finally ethene and CO₂. The absence of VC and higher concentrations of c-1,2-DCE may indicate that this process is stalling at c-1,2-DCE. Of note, the half life of VC is very short in comparison to c-1,2-DCE, and the compound may disappear while concentrations of c-1,2-DCE continue to accumulate.

Free-phase or residual LNAPL, present in the subsurface, likely acts as an electron donor in this anaerobic process. The aerobic conditions created by air/bio sparging would cause reductive dechlorination to cease near the pilot test. This would be accompanied by the increased activity of the aerobic bacteria that would use the LNAPL as the substrate for growth. While the degradation of the CVOCs by anaerobic bacteria would cease under the aerobic conditions, the bio sparging would strip the CVOCs from the subsurface soil and groundwater, while at the same time, the aerobic bacteria would consume the LNAPL. Upon ceasing the air sparging, sufficient biochemical oxygen demand would likely be left in the subsurface such that anaerobic conditions would quickly return after sparging was discontinued, and reductive dechlorination processes of CVOCs would likely resume shortly thereafter. In the event that sufficient LNAPL to serve as electron donor is not left at the end of the air/bio sparging and anaerobic biodegradation of the CVOCs is desired to be continued, substrate to serve as electron donor for the anaerobic bacteria can be injected. This would promote the continued anaerobic bio-degradations of the CVOCs following removal of the LNAPL through aerobic process.

7.3.3 Biological Indicators

Baseline and post-pilot groundwater samples were sent for PLFA analysis to help assess microbial response to changes in the environment created by the air/bio sparge pilot test.

Results of this test are presented in Table 6-2. Appendix 6 contains graphs comparing pre-and post-pilot PLFA analyses results.

As part of the PLFA analysis, viable biomass concentrations were analyzed to provide an indicator for overall bacterial growth. Generally, biomass levels which increase or decrease by at least an order of magnitude are considered to be significant. Analytical results, summarized in Table 6-2, show that, with the exception of MW-11S and PZ-AS-02 (the furthest well in each direction from the sparge trench), a slight increase in biomass was observed ranging between 19 percent and 161 percent. In general, greater increases were observed in wells located to the southeast of the sparge trench. A drop in biomass was observed at MW-11S, but considering the distance of this sampling point from the air/bio sparge trench, it is uncertain if this change was a result of the air/bio sparge operation, or because of groundwater movement created by pressure gradients caused by the sparge operation.

PLFA analysis was further evaluated in terms of community structure that was analyzed for specific groups of bacteria. Proteobacteria populations, which represent the majority of hydrocarbon degrading bacteria, slightly increased in post-pilot test samples. Firmicutes, indicative of anaerobic fermenting bacteria, showed a slight decrease in the post-test samples, which indicates the creation of aerobic conditions. Sulfur reducing bacteria (SRB) to Actinomycetes ratios were detected in low proportion that further provides evidence of an aerobic environment. Metal reducing bacteria that thrive in anaerobic environments showed no significant change, however, in post-test samples.

Ratios for slowed growth and for decreased permeability of cell membrane provide insight on the health of a bacteria community and how it responds to the conditions present in the environment. Physiological results of PLFA analysis indicated that a decrease in the slowed growth ratio occurred between baseline and post-test events at all wells except MW-11S. In addition, four out of the six wells monitored showed a decrease in the permeability ratio from baseline to post-test sampling. These results generally indicate that sparge operations created a more favorable environment for the bacteria present in the subsurface.

7.3.4 Summary

A pilot air/bio sparge test was performed to provide data to evaluate the applicability and effectiveness of the bio-sparging technology for the bioremediation of residual LNAPL.

The implementation of this test included:

- Obtaining relevant NJDEP permits for air emissions from the system and discharge of water from trench construction
- Construction of the horizontal sparge trench
- Installation of five temporary piezometers for monitoring the performance of the system
- Performing the pilot test
- Monitoring of field parameters before, during, and after the test at the five newly installed temporary piezometers and one existing monitoring well
- Collecting groundwater samples to document baseline conditions and assess the effects of the technology

The most challenging aspect of in situ remediation is to be able to influence the subsurface environment and provide the necessary treatment amendments to the target treatment zone (i.e., oxygen for aerobic bioremediation). At the Diamond Head site, the pilot test results clearly indicate that the air/bio sparge test successfully influenced the subsurface environment—creating and maintaining aerobic conditions in the shallow saturated zone at the site. Specifically, using horizontal injection wells installed at a depth just above the interface between the poorly sorted surficial sand and gravel layer and the silty clay layer, aerobic conditions were observed and sustained at all testing points used during the test at distances up to 20 feet from the trench. This corresponds to a 40-foot spacing between horizontal injection wells. These conditions were observed while operating at one of the lower injection rates (0.6 scfm/foot of well screen, 8 scfm total). The radius of influence may be higher at the higher injection rates tested, although this could not be confirmed because of the lack of monitoring points. The higher injection rates do, however, show more uniform distribution of oxygen to the subsurface. Overall, the system was determined to effectively introduce air and change subsurface conditions to aerobic up to the distance of the furthest well monitored during the pilot test.

Biological indicators suggest that aerobic conditions created by the air/bio sparge test resulted in increases in biomass, changes in the community structure to more aerobic bacteria, and creation of a generally more favorable environment for bacteria present in the subsurface. The test duration of 2 weeks, although increased from the initially planned 1 week, may have not been sufficiently long enough to demonstrate more significant changes in biological growth. In addition, alkaline conditions in groundwater (high pH) may be adversely affecting biological growth. Bacteria were, however, present prior to testing. This suggests that bacteria are capable of surviving in the current alkaline site conditions, and the creation of more favorable conditions would most likely promote growth. Additional bench tests may be warranted to determine if pH adjustment significantly affects biological growth. Depending on the results, pH adjustment conducted through injection of buffering solutions into the groundwater in conjunction with application of the air/bio sparge may be warranted. The need for pH adjustment and available methods for implementing pH adjustment should be evaluated during the feasibility study process.

Based on the above results, this technology is considered be applicable to site conditions—the technology promoted aerobic conditions that typically support aerobic degradation of petroleum contamination, and slight increases in biological growth were observed. More significant biological growth (and associated decreases in petroleum contamination) that would result from a long-term application of this technology cannot, however, be predicted based on the pilot test, possibly because of its relatively short duration.

In the anaerobic conditions in the subsurface prior to the start of the pilot test, reductive dechlorination of CVOCs was likely naturally occurring in the groundwater. This process includes the sequential removal of chlorine molecules from parent compounds (tetrachloroethene or trichloroethene) to trichloroethene, c-1,2-DCE, VC, and finally ethene and carbon dioxide. The absence of VC and higher concentrations of c-1,2-DCE may indicate that this process is stalling at c-1,2-DCE. Free-phase or residual LNAPL, present in the subsurface, likely acted as an electron donor in this anaerobic process. The aerobic conditions created by air/bio sparging would cause reductive dechlorination to cease near the pilot test. This would be accompanied by the increased activity of the aerobic bacteria that would use the LNAPL as the substrate for growth. While the degradation of the CVOCs by anaerobic bacteria would cease under the aerobic conditions, the bio sparging would strip the CVOCs from the subsurface soil and groundwater, while at the same time, the aerobic bacteria would consume the LNAPL. Upon ceasing the air sparging, sufficient

biochemical oxygen demand would likely be left in the subsurface such that anaerobic conditions would quickly return after sparging was discontinued, and reductive dechlorination processes of CVOCs would likely resume shortly thereafter. In the event that sufficient LNAPL to serve as electron donor is not left at the end of the air/bio sparging and anaerobic biodegradation of the CVOCs is desired to be continued, substrate to serve as electron donor for the anaerobic bacteria can be injected. This would promote the continued anaerobic biodegradations of the CVOCs following removal of the LNAPL through aerobic process.

The potential for air/bio sparging to upset natural reductive dechlorination of CVOCs that may be occurring should not limit implementation of air/bio sparging at this site. Aerobic conditions established during sparging will likely be short-lived once sparging is stopped, and the saturated zone would quickly return to anaerobic conditions. Natural occurring dechlorinating bacteria would be killed in an aerobic environment, but would likely repopulate once anaerobic conditions are re-established. There is the potential that these two technologies could even be used alternately to selectively degrade CVOCs (anaerobically) and VOCs (aerobically) if reduction in the concentration of specific COCs is desired.

In summary, the air/bio sparge technology should be considered for further evaluation and potential full-scale application in areas with residual LNAPL at the Diamond Head site.

SECTION 8

Investigation Derived Waste Management

Section 8 describes the following:

1. Wastes and associated quantities generated from the investigation activities
2. Waste sampling results
3. Onsite waste management and offsite disposal of the generated wastes

8.1 Introduction

The following types of IDW and associated quantities were generated by the Phase 2 investigation activities:

- Water from the steam cleaning and power washing of the large pieces of equipment used during the investigation activities (drill rig and landfill excavation equipment) and from the decontamination of sampling equipment—two 55-gallon drums
- Drill cuttings from soil borings—one 55-gallon drum
- LNAPL from the pilot recovery test—one 55-gallon drum
- Overpack drums containing drums (crushed or intact) removed from the landfill—two 95-gallon drums
- PPE—two 55-gallon drums
- General trash and cardboard

A trash dumpster was used to collect general trash and cardboard. The trash and cardboard were picked up for disposal on a routine basis.

Drums used to contain wastes were Department-of-Transportation-(DOT)-approved, open-top, 55-gallon steel drums. The drums used to overpack the drums removed from the landfill were 95-gallon polyethylene drums. The contents of each drum were identified on the drum. The drums were stored at the site while awaiting characterization and disposal.

The drill rig was dry-decontaminated between LIF locations and steam cleaned at the end of the LIF program. During the installation of piezometers, the rig was decontaminated using fire hydrant water and alconox between locations, followed by steam cleaning at the end of the drilling program. The landfill excavation equipment was power washed at the end of the landfill investigation. All decontamination fluids were collected for disposal.

8.2 Waste Sampling

The following waste materials were sampled to characterize for disposal purposes:

- Overpack drums containing crushed drums removed from the landfill for TCL, TAL, TCLP, and ignitability and corrosivity

- LNAPL from the pilot recovery test for TCL, TAL, TCLP, and ignitability and corrosivity
- Decontamination fluids from the decontamination of sampling equipment—TCL, TAL, and ignitability and corrosivity

The results for the overpack drum sampling are presented in Section 3 for the TCL and TAL analyses and in Table 8-1 for the TCLP and ignitability and corrosivity analyses. The tables note only detected compounds. The full results are provided in Appendix 2 for the TCL and TAL analyses and in Appendix 7 for the TCLP analyses.

The results for the LNAPL sampling are presented in Section 5 for the TCL and TAL analyses and in Tables 8-2 and 8-3 for the TCLP and ignitability and corrosivity analyses. The tables note only detected compounds. The full results are provided in Appendix 4 for the TCL and TAL analyses and in Appendix 7 for the TCLP analyses.

The results for the decontamination water sampling are presented in Table 8-4 for the TCL and TAL analyses and in Table 8-3 for the ignitability and corrosivity analyses. The tables note only detected compounds. The full results are provided in Appendix 7.

The drill cuttings were not sampled during this phase of investigation. Since the piezometers were installed within the same areas that were investigated during the Phase 1 RI, the disposal characterization results from the Phase 1 were used to characterize these cuttings for disposal at the end of this phase of investigation.

8.3 Waste Characterization

In consultation with USEPA, a determination was made on the classification of the different wastes.

The results of the above waste characterization analyses indicated that all the wastes contained various contaminants. The detected concentrations were, however, below the TCLP limits and, therefore, the wastes were not considered to be characteristically hazardous. In addition, the LNAPL and the decontamination water were found not to be ignitable and to have a pH that would not result in them being a corrosive hazardous waste. Results from the Phase 1 RI were also used to supplement the Phase 2 results in determining the classifications of the generated wastes.

Finally, in consultation with USEPA, the determination was made during the Phase 1 RI that there is no information to suggest that the wastes from the site should be classified as listed hazardous wastes.

Based on these determinations, the wastes will be sent for disposal as nonhazardous waste. Wastes will be transported offsite for disposal at permitted facilities following applicable federal and state regulations.

Conclusions and Recommendations

This section describes the conclusions from the Focused Phase 2 Remedial Investigation and provides recommendations regarding the need for additional information. This information, as well as any other identified during remedial alternative evaluation in the FS, can be collected as part of the investigation supporting the design of the selected remedial alternative for the site. Conclusions presented in this section should be viewed within the limitations described in Section 1 of this TM.

9.1 Conclusions

Landfill Investigation

- The majority of the observed landfill contents consisted of municipal-type wastes with a lesser component of demolition-type debris.
- Twenty two features of interest were encountered throughout the landfill investigation. These features generally consisted of crushed steel 55-gallon drums, poly or fiberboard drums, and areas of refuse containing discernable zones of unique materials such as apparent polymers or resins.
- Samples collected to characterize the landfill's contents contained VOCs, SVOCs, pesticides, PCBs and metals. In all samples, concentrations from at least one class of compounds exceeded the NJDEP direct contact criteria.
- No spatial or vertical trends in contamination were observed from the characterization sampling although as expected, the data indicated pervasive contamination throughout the landfill.
- Some sample locations were biased towards areas of suspect contamination. These samples contained similar constituents and concentrations to that found in the remaining samples with the exception of one location (LTR-W-09) where the concentrations of many compounds in each category were significantly higher than at the remaining locations.
- The five features which were sampled contained VOCs and metals but only two of the five features contained concentrations above the NJDEP direct contact criteria. Three of the five features sampled contained SVOCs but only one compound exceeded criteria in one feature. Pesticides and PCBs were not detected in the sampled features.
- The classes of contaminants detected in the landfill samples are consistent with the classes of contaminants found in the surface and subsurface soils during the Phase 1 RI. And while concentrations in the landfill may exceed NJ direct contact criteria, the Phase 1 groundwater sampling results did not suggest that these constituents act as a source to groundwater contamination.

LNAPL Investigation

Overview

The lateral and vertical extent of LNAPL was evaluated through the implementation of the LIF investigation. Using these data together with data from the LNAPL recovery pilot test and specialized petrochemical analyses, multiple lines of evidence were developed to evaluate the mobility (i.e., pore fluid velocity) and recoverability of the LNAPL. This comprehensive evaluation determined that the LNAPL is present in the subsurface at high saturation levels and is distributed in the subsurface from the water table (approximately 2 feet bgs) through the saturated zone to depths of 16 feet bgs in some locations. These values confirmed LNAPL presence previously indicated only by LNAPL accumulation in monitoring wells and piezometers. The evaluation also determined, however, that despite the large in-well thicknesses and high saturation levels, the LNAPL remains extremely viscous and has a very low conductivity (less than 10^{-5} cm/s). Based on these characteristics, the LNAPL was found to be essentially immobile and therefore, poorly recoverable with any fluid recovery-based remediation system. Also the relatively immobile LNAPL is self-contained and therefore poses relatively low risk of future lateral migration.

Based on limited SPLP testing of LNAPL saturated soils, however, it was determined that some leaching potential exists for benzene and PCB isomers in areas of high LNAPL saturation (i.e., the areas where LNAPL accumulates in wells) and areas where the heterogeneous LNAPL exhibited the presence of lighter compounds. Remedial actions are therefore, warranted for at least the portions of the LNAPL plume that exhibited leaching potential. The remedial options should focus on in-situ or ex-situ treatment technologies because fluid recovery is not practicable. Supporting details from the LNAPL evaluation are presented in the following sub-sections. While some of the specific values may vary slightly between the multiple lines of evidence, the overall conclusions drawn from each line of evidence are consistent.

LIF

- Figure 4-7 shows the horizontal extent of the LNAPL at the site exceeding 10 %RE response of the LIF technology. A fluorescence response of less than 10% RE is considered "unaffected soil" absent of LNAPL. A response of **less than 15%** is indicative of residual LNAPL. A response of **less than 40% RE** appears to be LNAPL that is not leaching to groundwater. A response of more than 40% RE (shown with a green UVOST™ graphical fingerprint) appears to indicate the presence of LNAPL that may leach to groundwater. Figure 4-9 shows the horizontal extent of the LNAPL at the site exceeding 40% RE response. As seen in Figure 4-9, the area of the site that exceeds 40% RE, and is therefore potentially leaching to groundwater, is significantly smaller than the total area affected by LNAPL shown in Figure 4-7. The estimated total volume of soil (all soil horizons) containing LNAPL greater than 40% RE is 4,276 cubic yards or approximately 8-percent of the total volume of soil impacted with LNAPL with LIF response greater than 10%RE.
- The vertical occurrence of LNAPL at the site can be separated into two depth intervals: 1) at the water table and sometimes with an extended smear zone into the saturated fill-containing material/soil up to 9.5-feet bgs, and 2) occurring as a distinct deeper interval at depths of 10- to 15-feet bgs within silty/clayey soils. The highest concentrations of LNAPL are predominantly located near the water table within the fill layer, but are also present within the silty/clay soils in deeper portions of the LNAPL plume.

- The SPLP sampling results suggest that the LNAPL may be leaching contamination to groundwater. The single SPLP sample that exceeded criteria was collected within an area containing greater than 40% RE LIF response. All other SPLP samples were in areas of lesser LIF response.

Pilot Test – LNAPL Recovery

Groundwater Flow and LNAPL Thickness

- Groundwater flow directions and the occurrence of LNAPL are generally consistent with those noted during the Phase 1 RI in 2003.
- An area of high groundwater elevation occurs in the southeast corner of the site (MW-3 area) and groundwater flows radially away from this high toward the northeast, northwest, and southwest. Limited data are available for areas to the south and southeast but indications are that groundwater also flows radially away from the mounded area in these directions also.
- While variations in LNAPL thickness are noted between measurement events within the same well, and large variations in measured thickness can be observed over short distances between wells, the maximum thickness of LNAPL observed in 2008 is approximately 1-foot greater than observed in 2003.
- LNAPL was measured in wells in three separate areas of the site: the main plume around piezometers PZ-7 and PZ-10, a second area between MW-13S and PZ-14, and a newly observed occurrence at PZ-16. While it was not measured in wells in other areas of the site, the LIF data indicate its presence in the subsurface at various saturation concentrations. While the LNAPL may not be accumulating in these wells, it is still present in the subsurface in these areas.

LNAPL Recoverability Based on Pilot Test Results

- The calculated results of the baildown tests at piezometers PZ-7 and PZ-10, located approximately 30 feet apart, were fairly similar and indicated the following subsurface conductivity and transmissivity for the LNAPL:
 - PZ-7: Conductivity for LNAPL (K_o) = 1.49×10^{-5} cm/sec
(maximum K_o range: 5.2×10^{-6} cm/sec and 4.2×10^{-5} cm/sec)
Transmissivity for LNAPL (T_o) = 2.91×10^{-3} cm²/sec
 - PZ-10: Conductivity for LNAPL (K_o) = 2.12×10^{-5} cm/sec
(maximum K_o range: 3.4×10^{-5} cm/sec and 1.52×10^{-5} cm/sec)
Transmissivity for LNAPL (T_o) = 3.96×10^{-3} cm²/sec
- Given these conductivity values and a typical LNAPL gradient, the effective LNAPL velocity at PZ-7 is calculated (using the K_o = 1.49×10^{-5} cm/sec value) to be 9×10^{-7} cm/sec or approximately 1 foot per year suggesting limited LNAPL mobility.

LNAPL Chemical Composition

- LNAPL at the site contains more diesel range organics (DROs) than the gasoline range organics (GROs). The following compounds or classes of compounds were detected in the LNAPL sample: benzene, toluene, ethylbenzene, xylenes as well as a number of other volatile and semi-volatile organic compounds consistent with a petroleum matrix; two PCBs (Arochlor 1232 and Arochlor 1260); and a variety of metals, including lead and cyanide.

LNAPL Mobility and Recoverability Based on Specialty Testing

- The maximum LNAPL conductivity calculated based on the results of the laboratory petrochemical analysis is 8.3×10^{-7} cm/sec, which is lower than the design standard hydraulic conductivity for a hazardous waste landfill liner (1×10^{-6} cm/sec). At its most transmissive state, the high viscosity of the LNAPL (estimated at 271 centipoise at a temperature of 50 degrees Fahrenheit, roughly 2 orders of magnitude higher than the site water), inhibits its mobility.
- The estimated velocity of the LNAPL was calculated to range from about 0.004 foot/year up to a maximum of only about 0.1 foot per year suggesting limited LNAPL mobility.
- Simplified recovery modeling of the LNAPL at the site indicated that the LNAPL is generally not practicably recoverable. Results of the recovery modeling over a time period of 30 years showed that at most, approximately 5 to 6 % of the LNAPL volume could be recovered.
- The results of the LNAPL mobility and recoverability assessment must be interpreted within the context of the assumptions used for the calculations. However, all practical effort was made to present conservative parameter values so that the result may possibly be an over-estimate of the potential mobility and recovery of the LNAPL.

Pilot Test – Air/Bio Sparge

- The pilot test results clearly indicate that the air/bio sparge test successfully influenced the subsurface environment - creating and maintaining aerobic conditions in the shallow saturated zone.
- Biological indicators suggest that aerobic conditions created by the air/bio sparge test resulted in increases in biomass, changes in the community structure to more aerobic bacteria, and creation of a generally more favorable environment for bacteria present in the subsurface. Based on the above results, this technology is considered applicable to site conditions.

9.2 Recommendations

Based on the results of the Phase 2 RI, the mobility of the LNAPL present at the Diamond Head site is extremely limited and is not practically recoverable using fluid recovery means. The remedial action objectives and technology screening performed at the beginning of the focused Phase 2 activities should therefore, be reviewed to include this newly acquired information.

The following additional activities are recommended as part of the remedial design activities.

Landfill

- The edge of the landfilled materials should be delineated to be able to determine the areal extent of the landfill that will need to be addressed through the selected remedial alternative.
- Additional groundwater data should be collected to confirm the Phase 1 results. These results suggested that the landfill does not serve as a source to groundwater contamination.

LNAPL

- Additional SPLP data should be collected to better map the extent of LNAPL which is leaching contaminants to groundwater.
- Before the selected remedial action is implemented, a delineation of the extent of the LNAPL should be completed in areas that were not addressed during the Phase 1 RI, and that could not be completed during this focused investigation.
- If AS is selected as a remedial technology for the site, some additional bench scale testing is recommended to determine the effect of the pH on biological activity and its ability to reduce the leachability of LNAPL.

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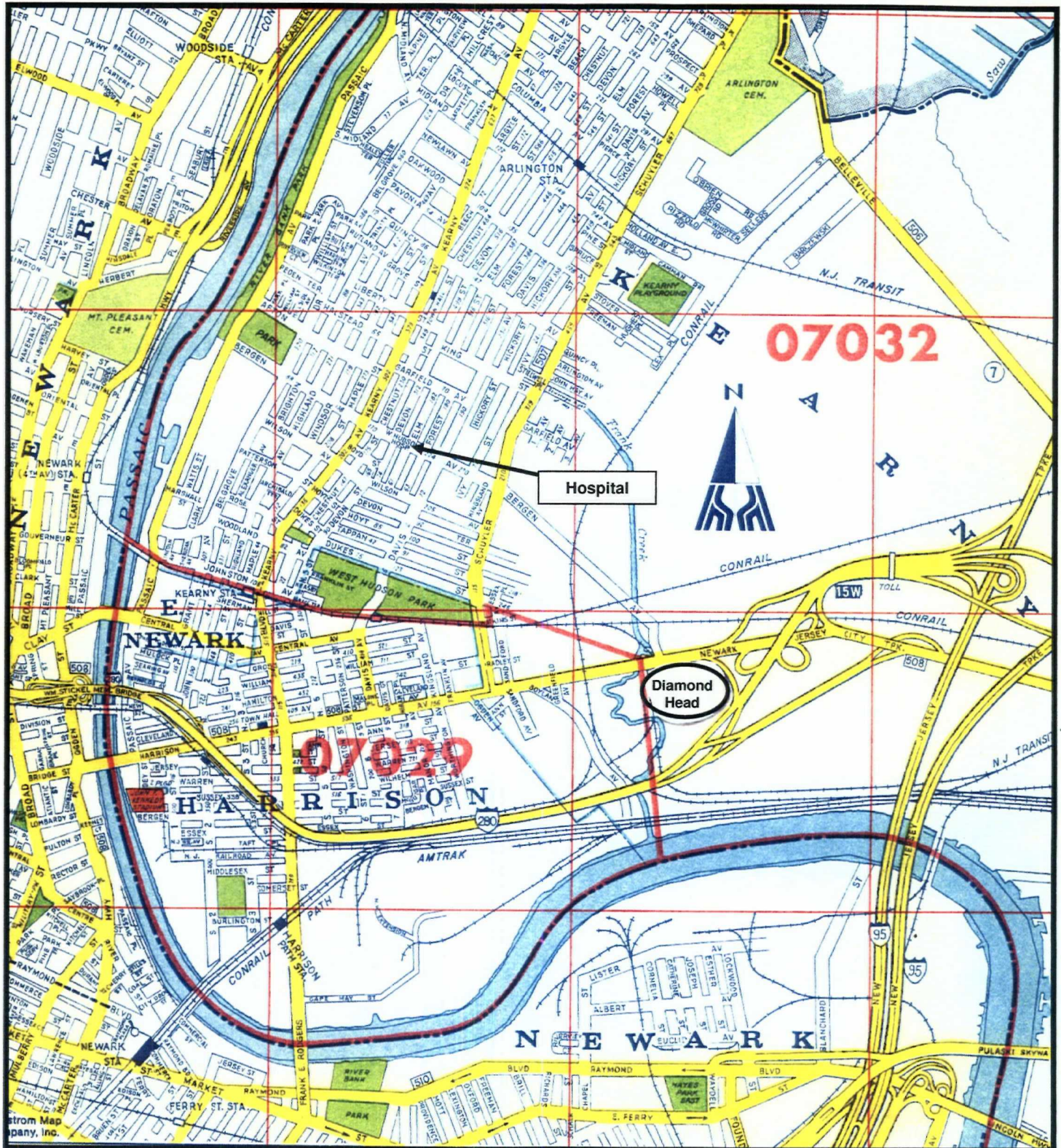
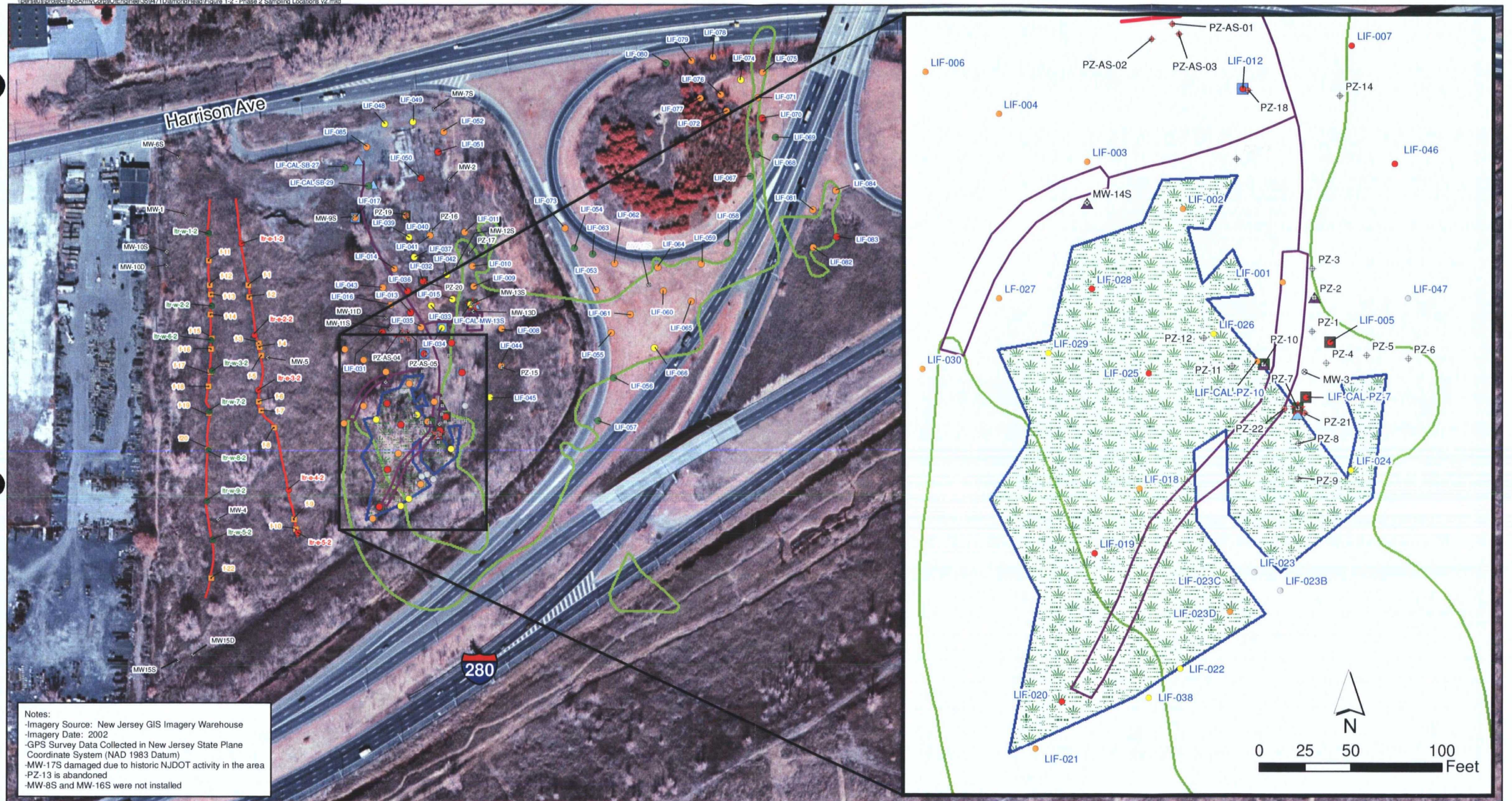


Figure 1-1

Diamond Head Oil - Site Location Map

**Vacant Lot: East of Campbell Foundry - 1235 Harrison Ave.
Kearny, NJ 07032 (Hudson County)**

See Also: USGS 7.5' Quadrangle: Elizabeth, NJ: Photorevised 1981
40° 44' 50" lat., 74° 07' 55.9" long. (NAD 83)



Legend

- ⊛ Phase 1 Monitoring Wells
- ⊕ Phase 1 Piezometers
- ⊕ Phase 2 RI Temporary Piezometers
- West Trench Samples
- East Trench Samples
- ⊠ Trench Features

LIF Locations - Maximum % RE

- RE Response > 100%
- RE Response 60 - 100%
- RE Response 10 - 60%
- RE Response > 10%
- Boring terminated due to subsurface refusal

- ★ LNAPL GW Pair Samples (PZ-7, MW-13S)
- ▲ SPLP Samples (MW-13D, MW-14S, PZ-2, PZ-10)
- ▲ LIF Baseline Logs (SB-27, SB-29, PZ-7, PZ-10, MW-13S)
- Intact Core Samples (LIF-040, LIF-32, LIF-CAL-PZ-7, LIF-005)
- LIF Soil Boring Logs (LIF-017, LIF-034, LIF-012)
- LNAPL Baseline LIF Correlation (PZ-7, PZ-10, MW-13S)

- Landfill Trench Centerline
- Air Sparge Trench
- Temporary Gravel Road
- Extent of Historical Source Area (1976 Aerial Photo)
- Delineated Wetlands
- Damaged / Abandoned Well

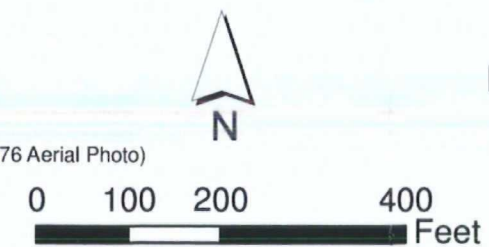
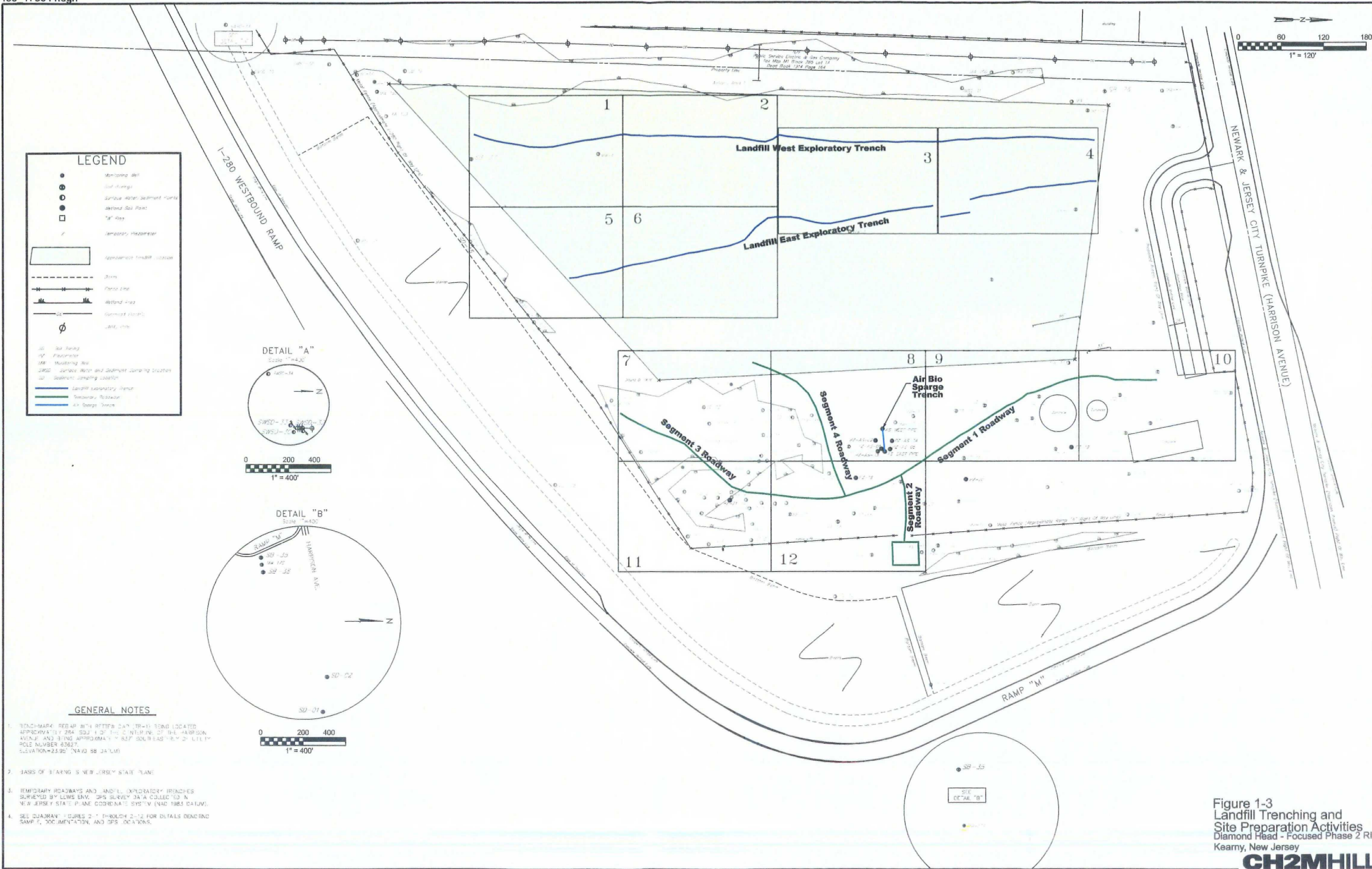
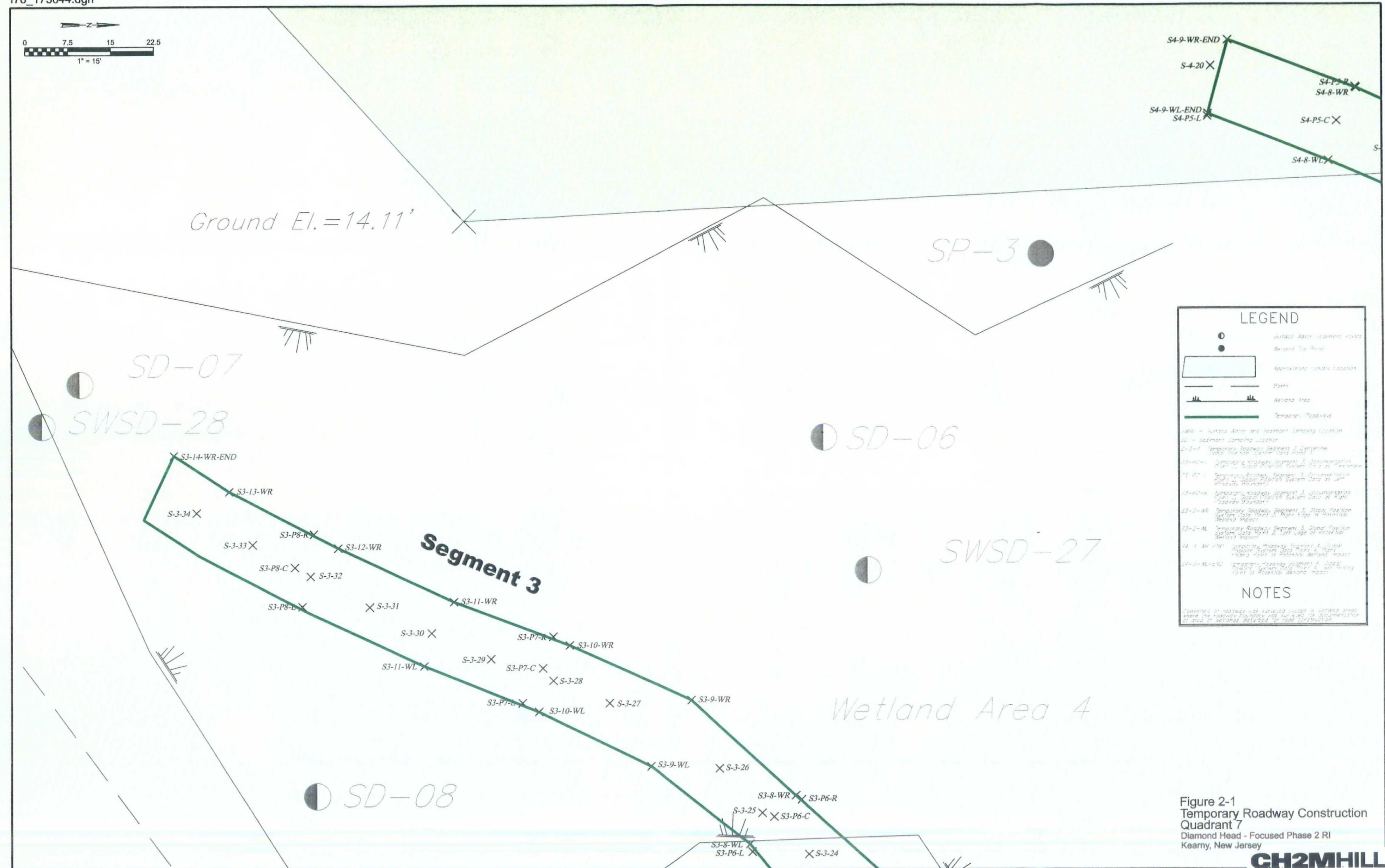
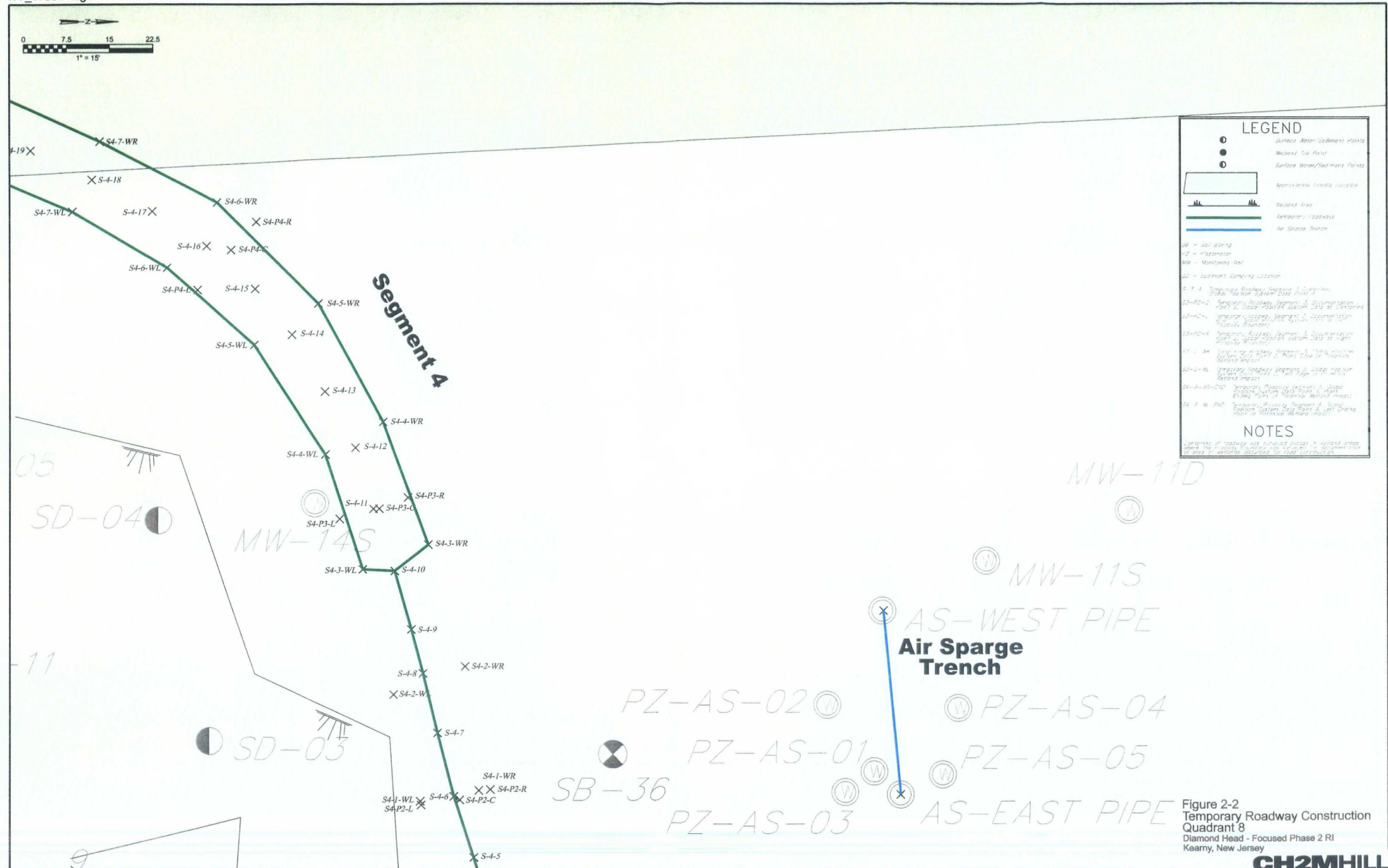
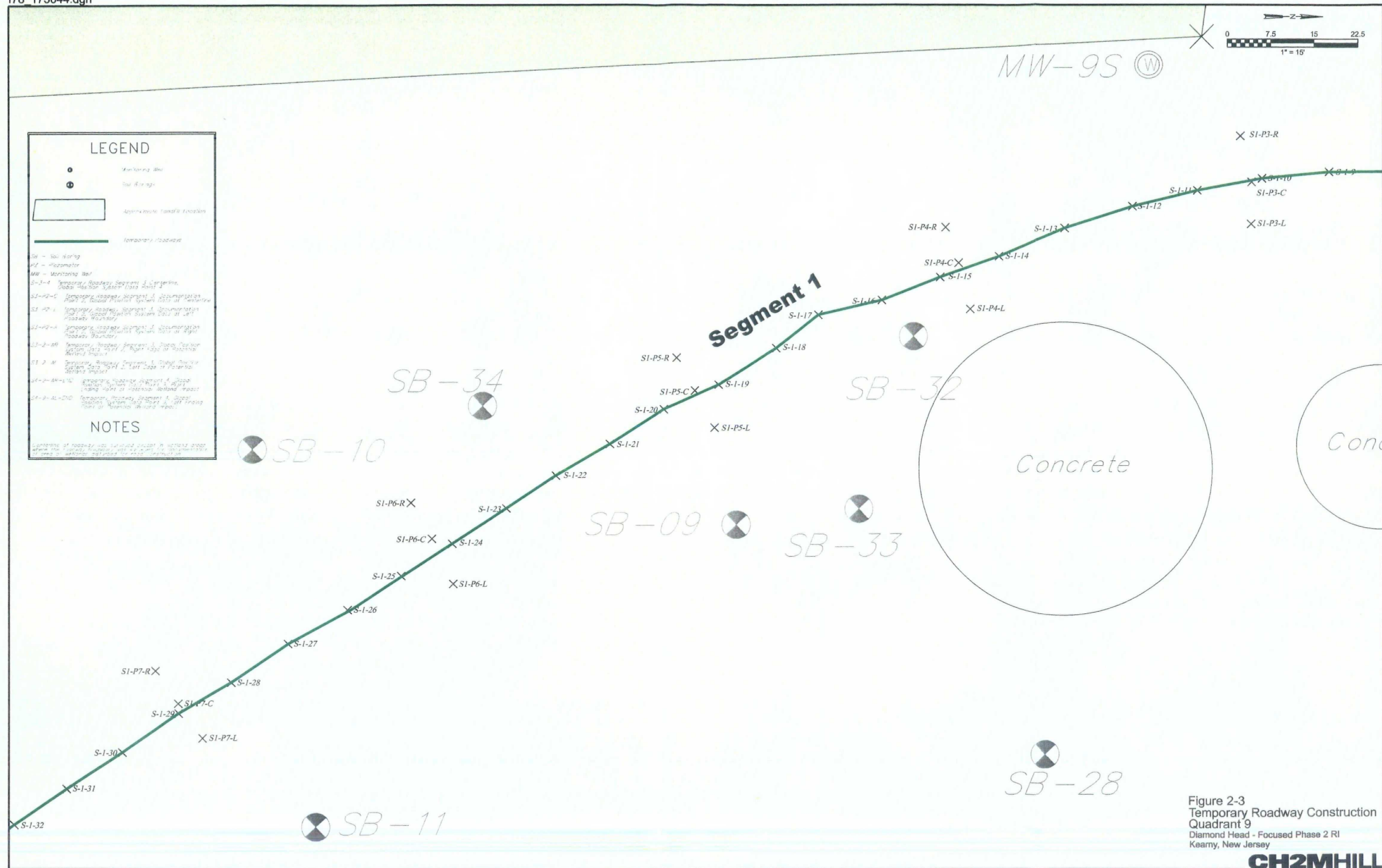


Figure 1-2
 Phase 2 Sampling Locations
 Diamond Head - Focused Phase 2 RI
 Kearny, NJ









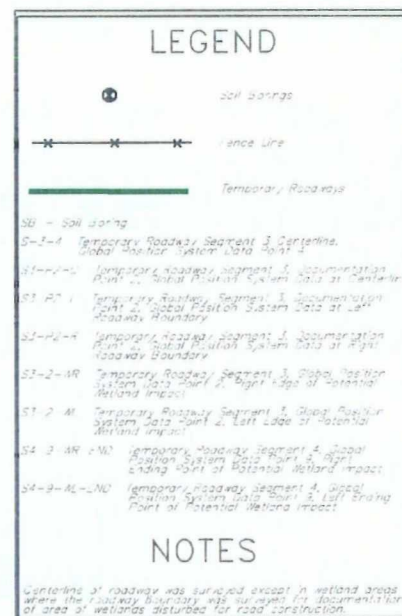
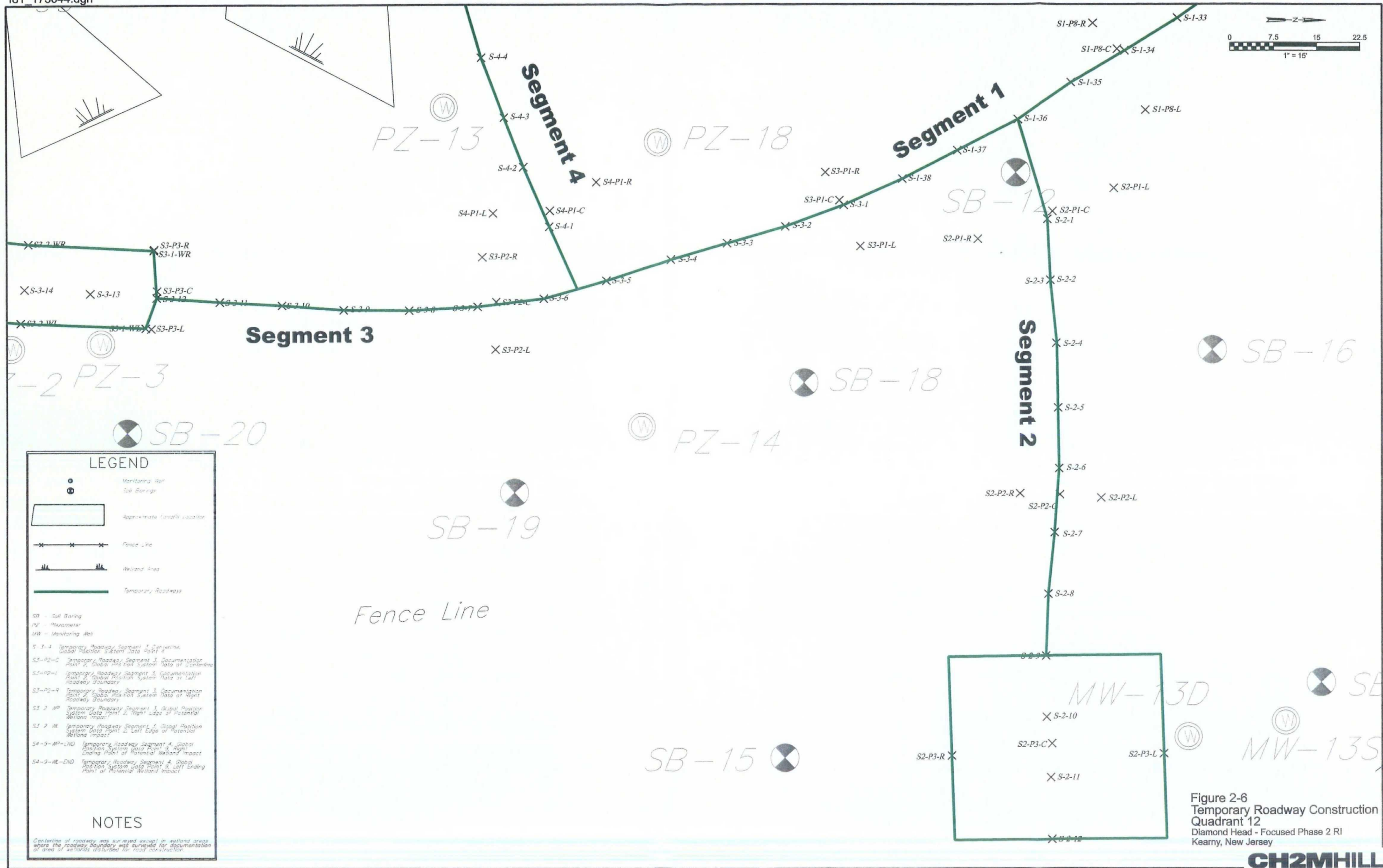
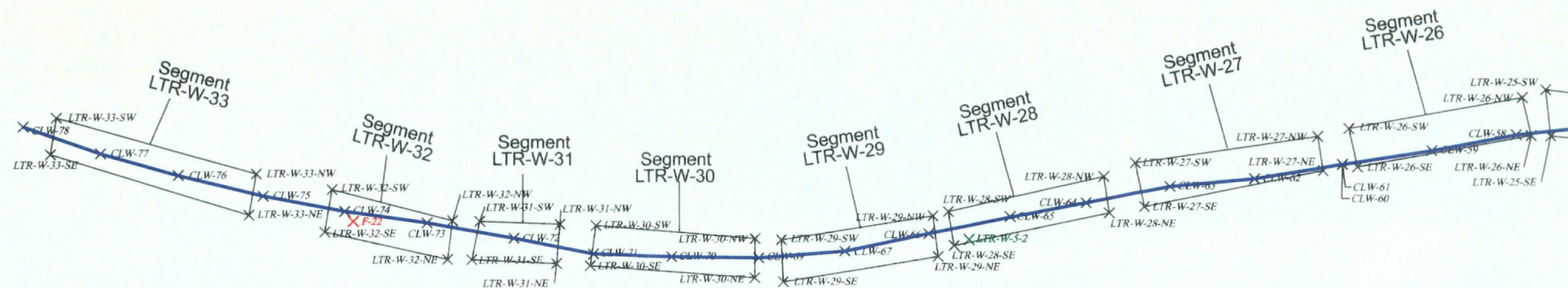
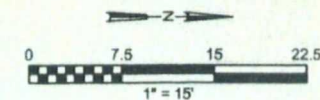


Figure 2-4
Temporary Roadway Construction
Quadrant 10
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey







Landfill West Exploratory Trench

SB-37

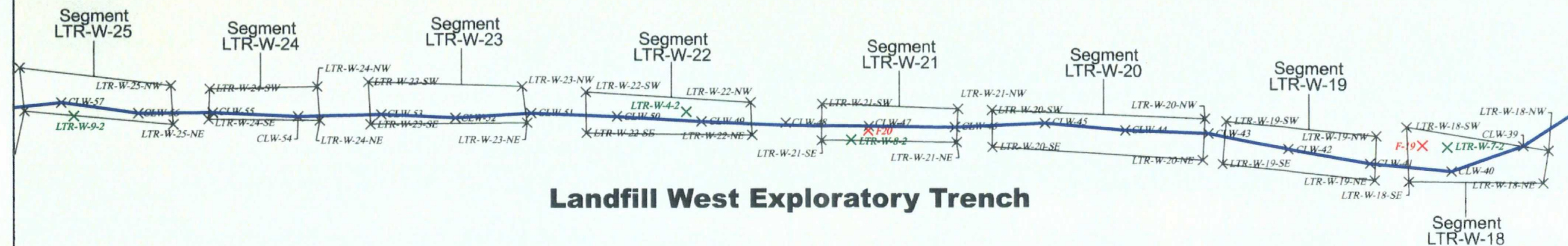
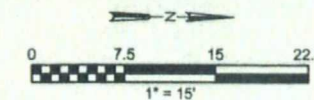
MW-4

LEGEND

- Monitoring Well
- Soil Borings
- Approximate Landfill Location
- Landfill Exploratory Trench
- SB - Soil boring
- LTR-F-5-NW Landfill Exploratory Trench, East Trench, Segment 5, Northwest Corner
NE - Northeast
SE - Southeast
SW - Southwest
- LTR-W-7-SE Landfill Exploratory Trench, West Trench, Segment 7, Southeast Corner
NE - Northeast
SE - Southeast
SW - Southwest
- LTR-F-2 Landfill Exploratory Trench, East Trench, Sample #2
- F-1 Feature of Interest #1
- CLE-12 Centerline of East Trench, Global Positioning System Data Point 12
- CLW-5 Centerline of West Trench, Global Positioning System Data Point 5

Figure 3-1
Landfill Exploratory Trench Activities
Quadrant 1
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL



LEGEND

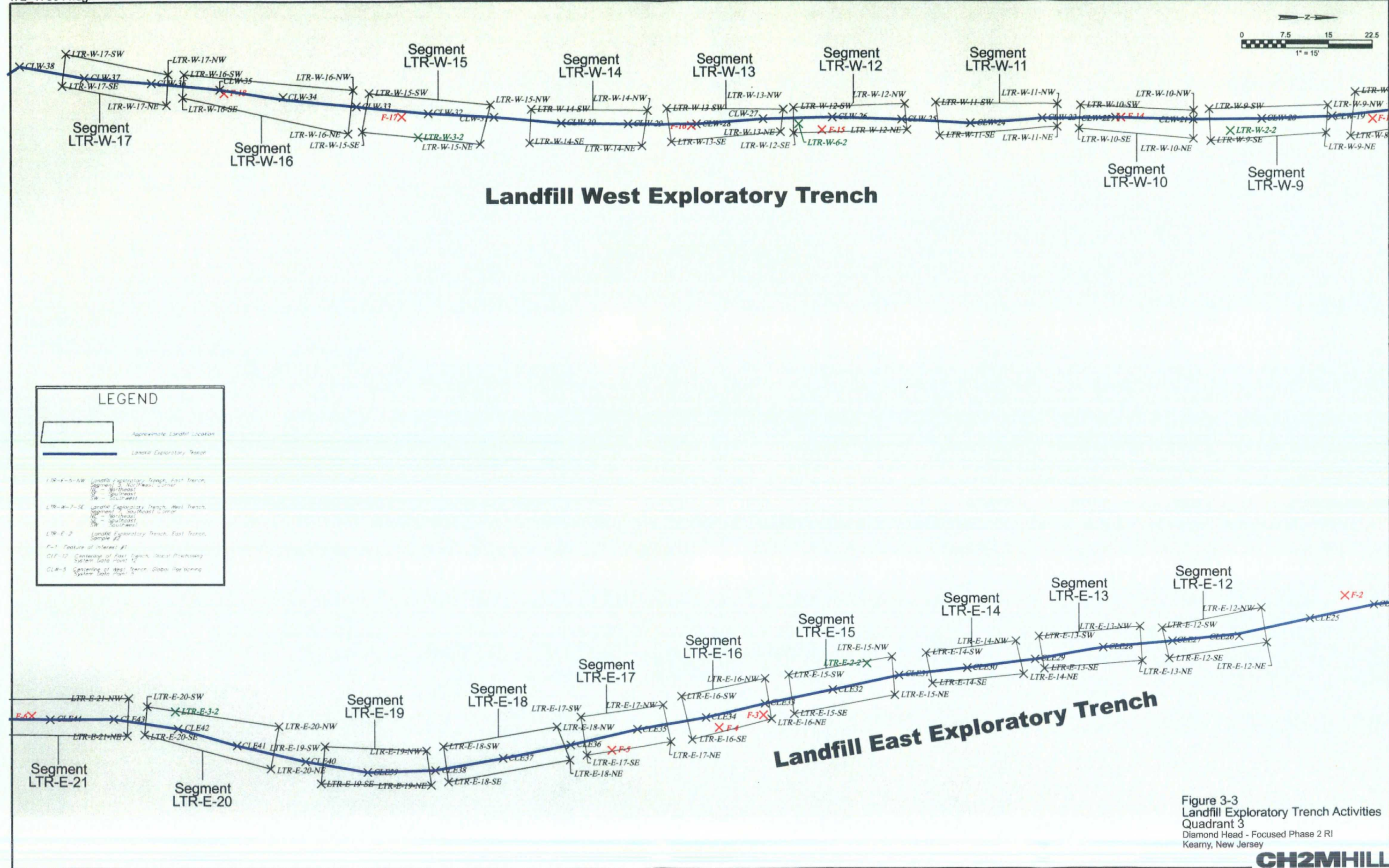
- Approximate Landfill Location
- Landfill Exploratory Trench
- LTR-E-5-NW Landfill Exploratory Trench, East Trench, Segment 5, Northwest Corner
NE - Northeast
SE - Southeast
SW - Southwest
- LTR-W-7-SE Landfill Exploratory Trench, West Trench, Segment 7, Southeast Corner
NE - Northeast
SE - Southeast
SW - Southwest
- LTR-E-2 Landfill Exploratory Trench, East Trench, Sample #2
- I-1 Feature of Interest #1
- CLW-12 Centerline of East Trench, Global Positioning System Data Point 12
- CLW-5 Centerline of West Trench, Global Positioning System Data Point 5

NOTE

Location of LTR-W-4-2 is approximate.

Figure 3-2
Landfill Exploratory Trench Activities
Quadrant 2
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL



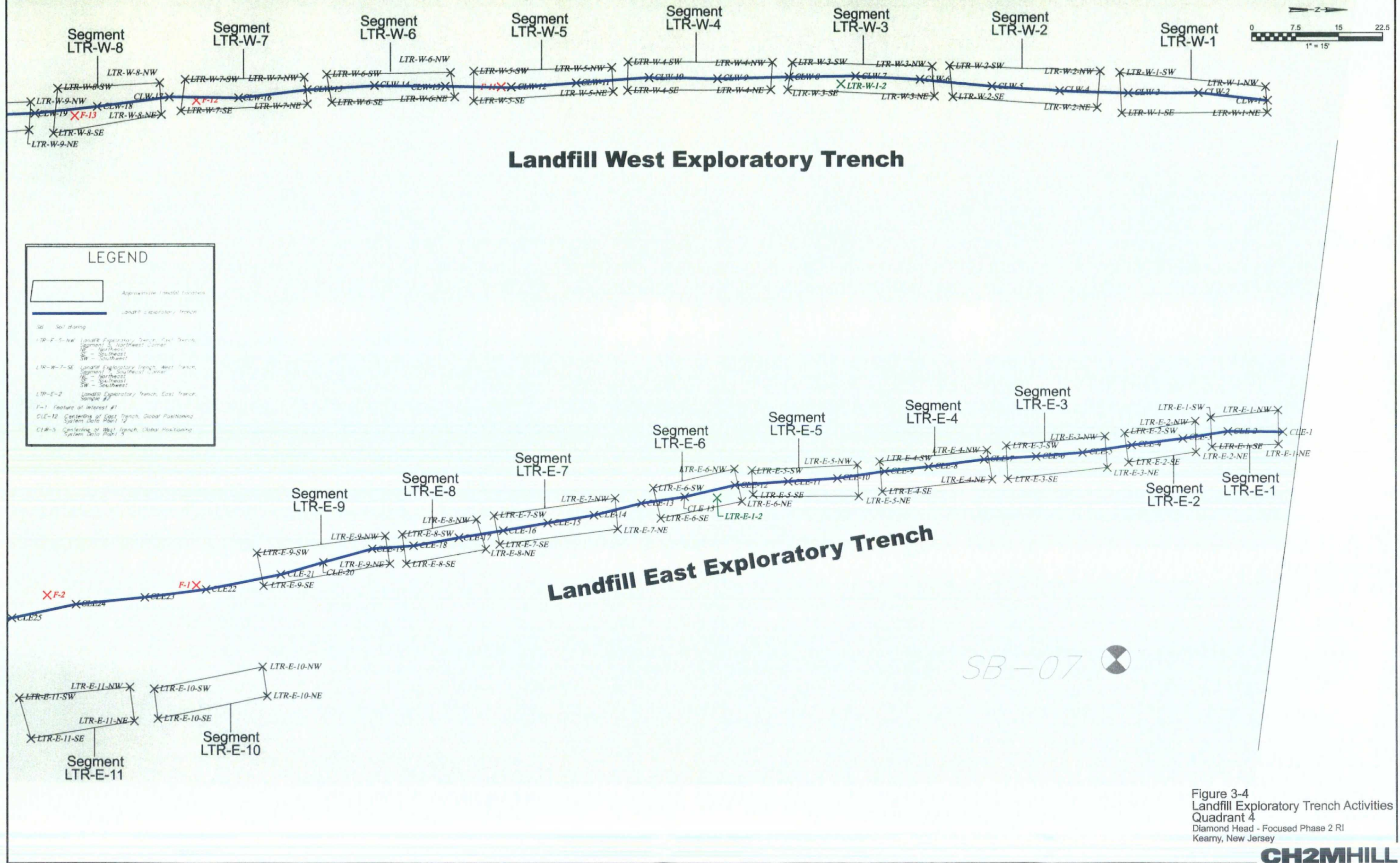


Figure 3-4
Landfill Exploratory Trench Activities
Quadrant 4
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

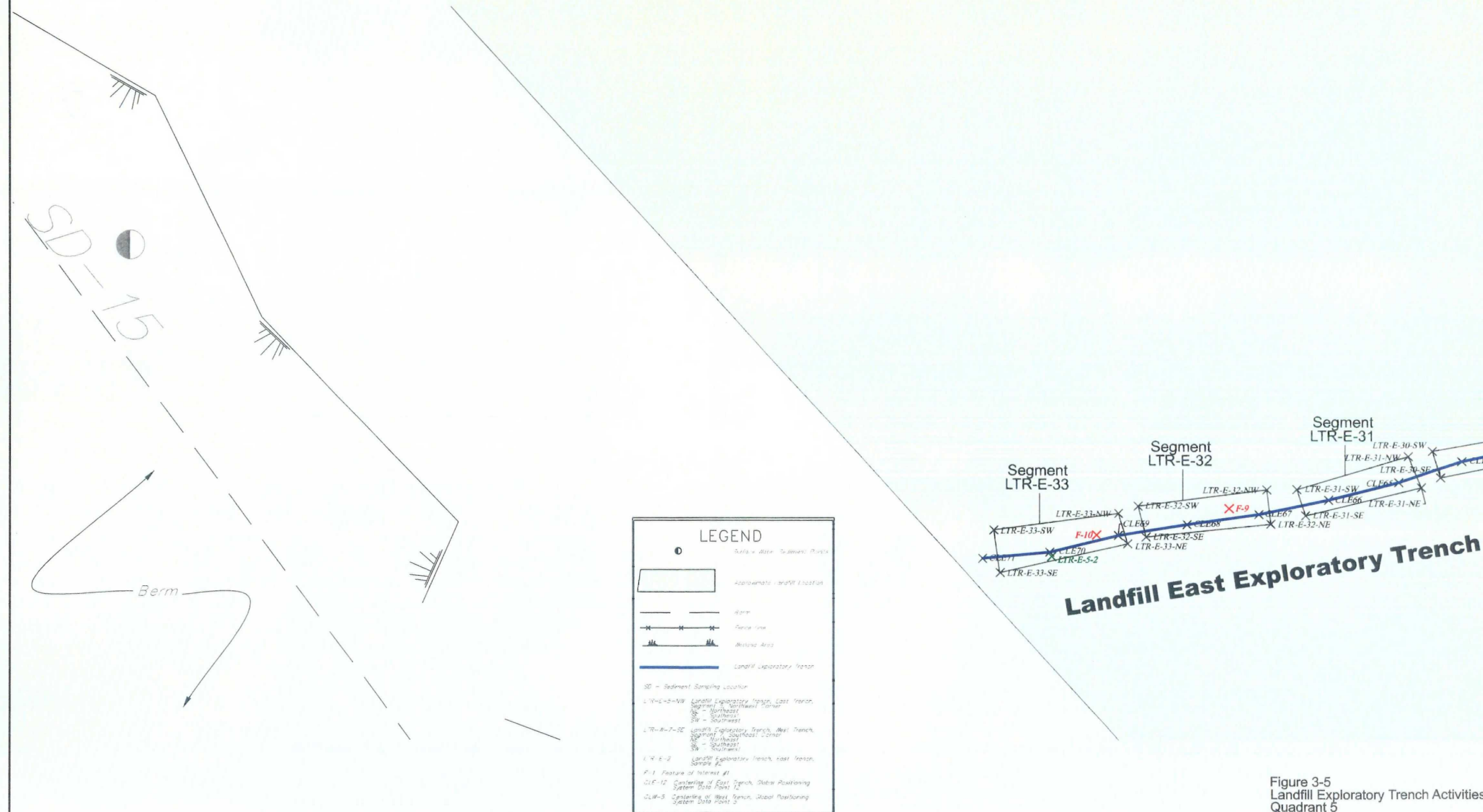
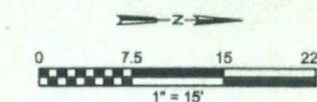


Figure 3-5
Landfill Exploratory Trench Activities
Quadrant 5
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

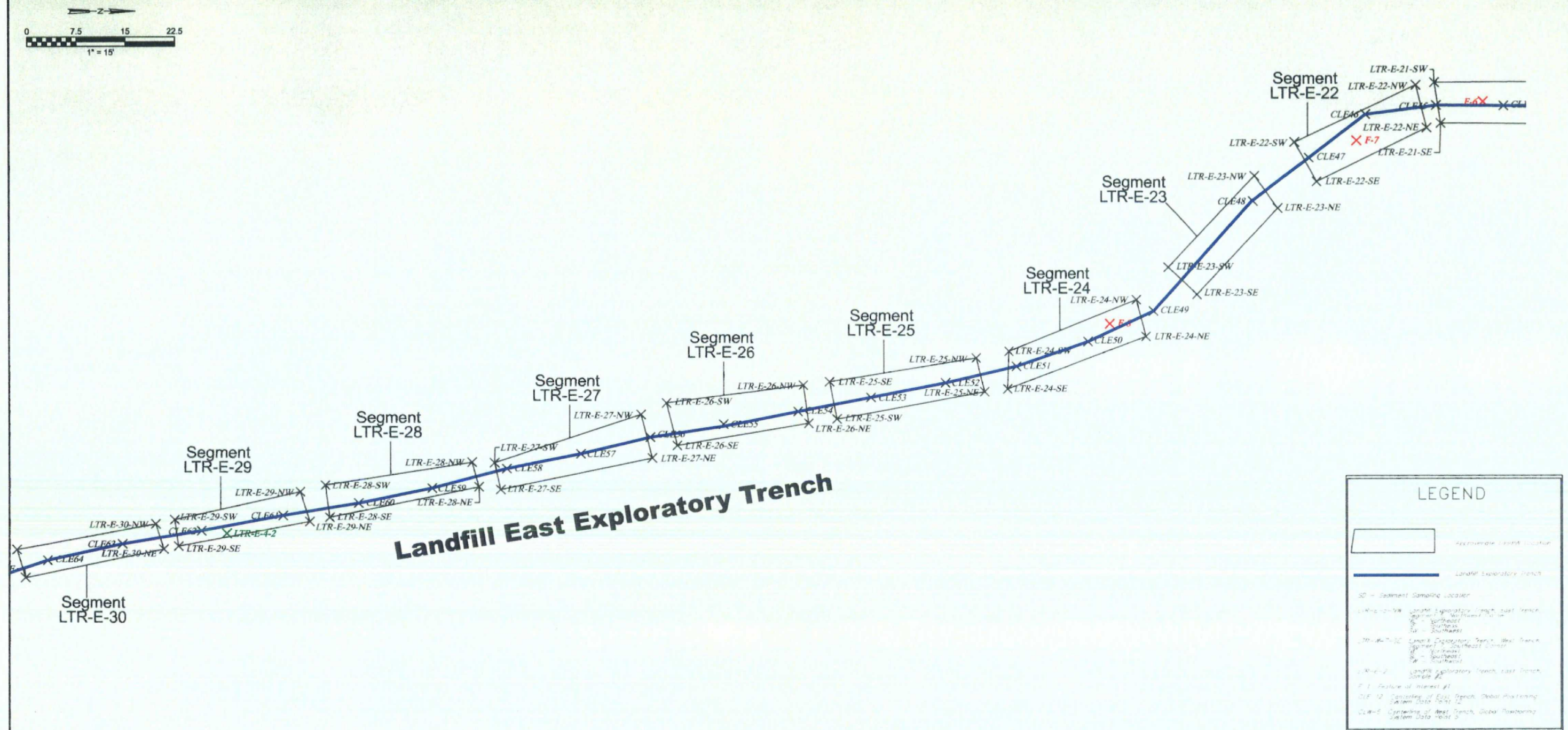


Figure 3-6
Landfill Exploratory Trench Activities
Quadrant 6
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

BS_17304.dgn

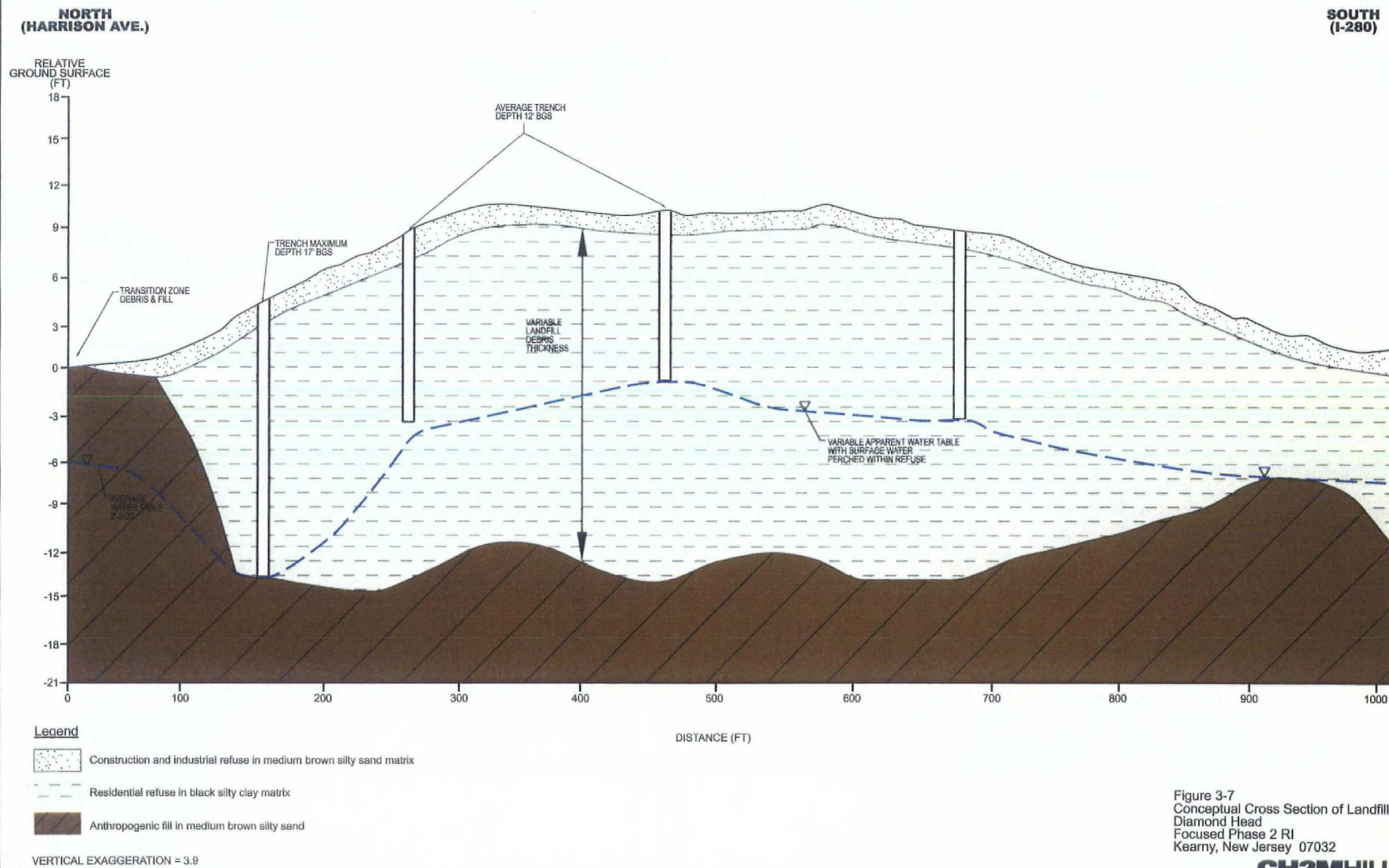
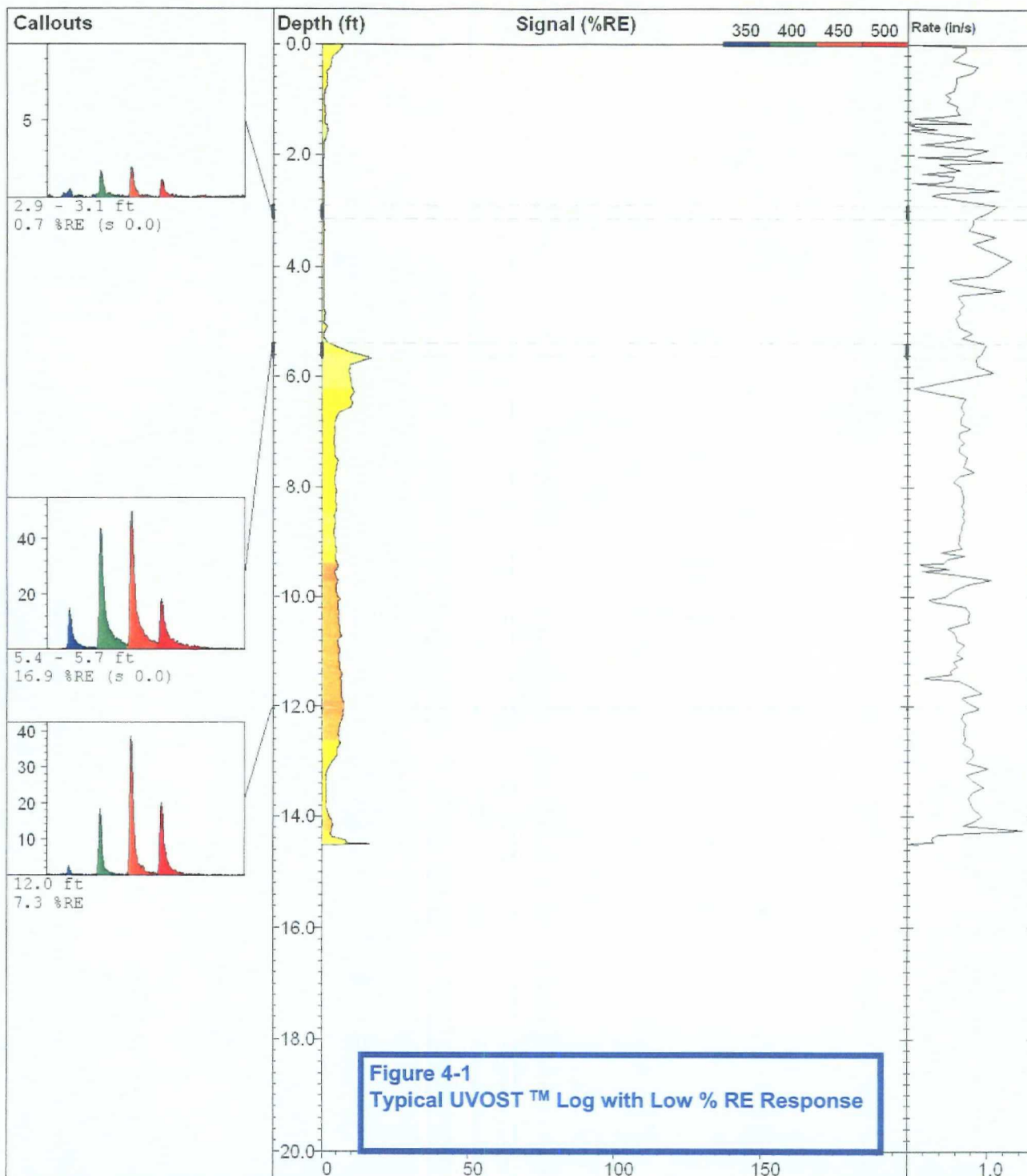


Figure 3-7
Conceptual Cross Section of Landfill
Diamond Head
Focused Phase 2 RI
Kearny, New Jersey 07032

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TECHNOLOGIES**
FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

LIF-008

Site:
Diamond Head Superfund

Client:
CH2M Hill

Job:
359471.03.02.01

Latitude / Datum:
Unavailable / NA

Longitude / Fix:
Unavailable / NA

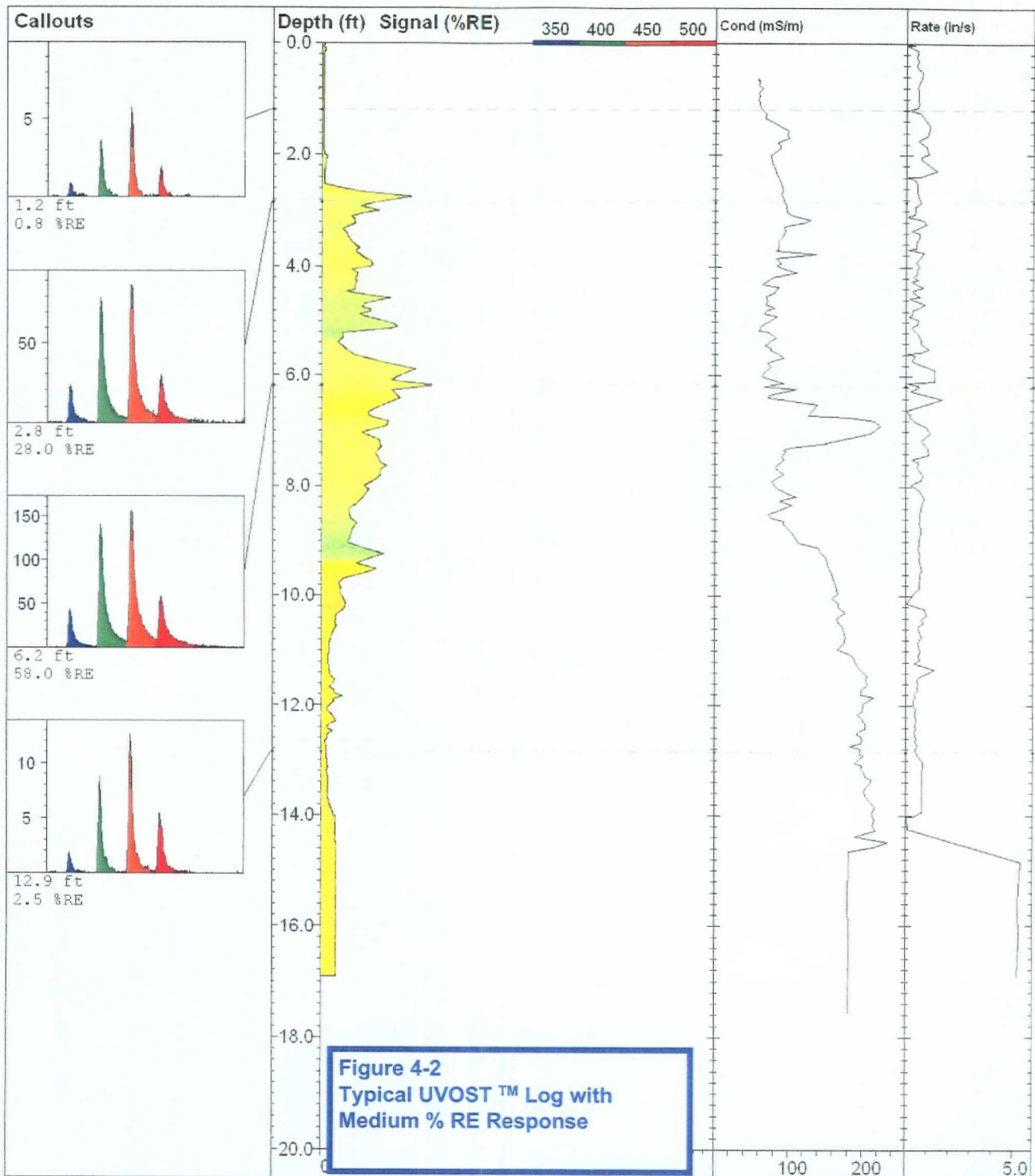
Operator/Unit:
T.Rudolph/LAB01


UVOST By Dakota
www.DakotaTechnologies.com

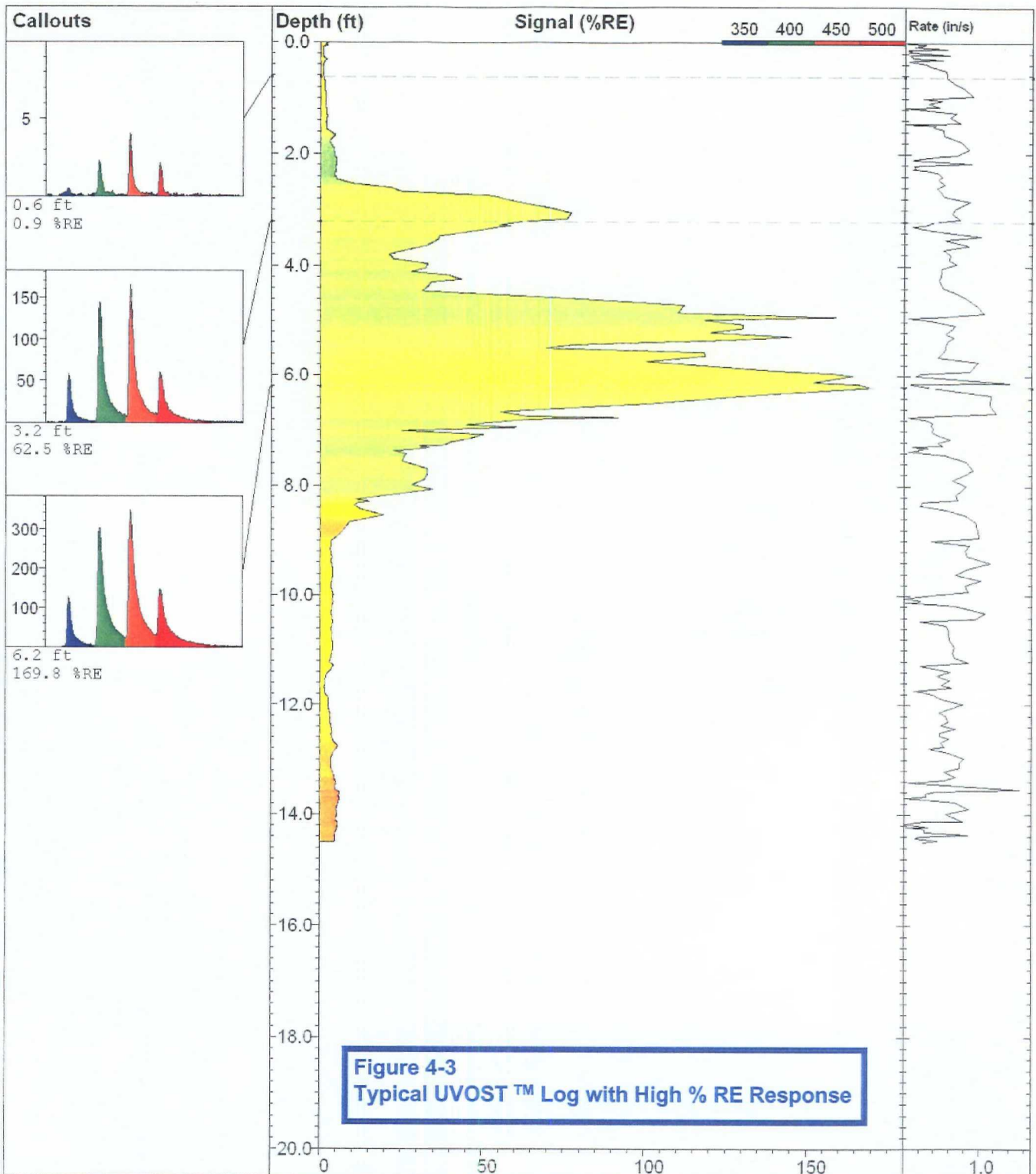
Final depth:
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Max signal:
16.9 % @ 5.66 ft

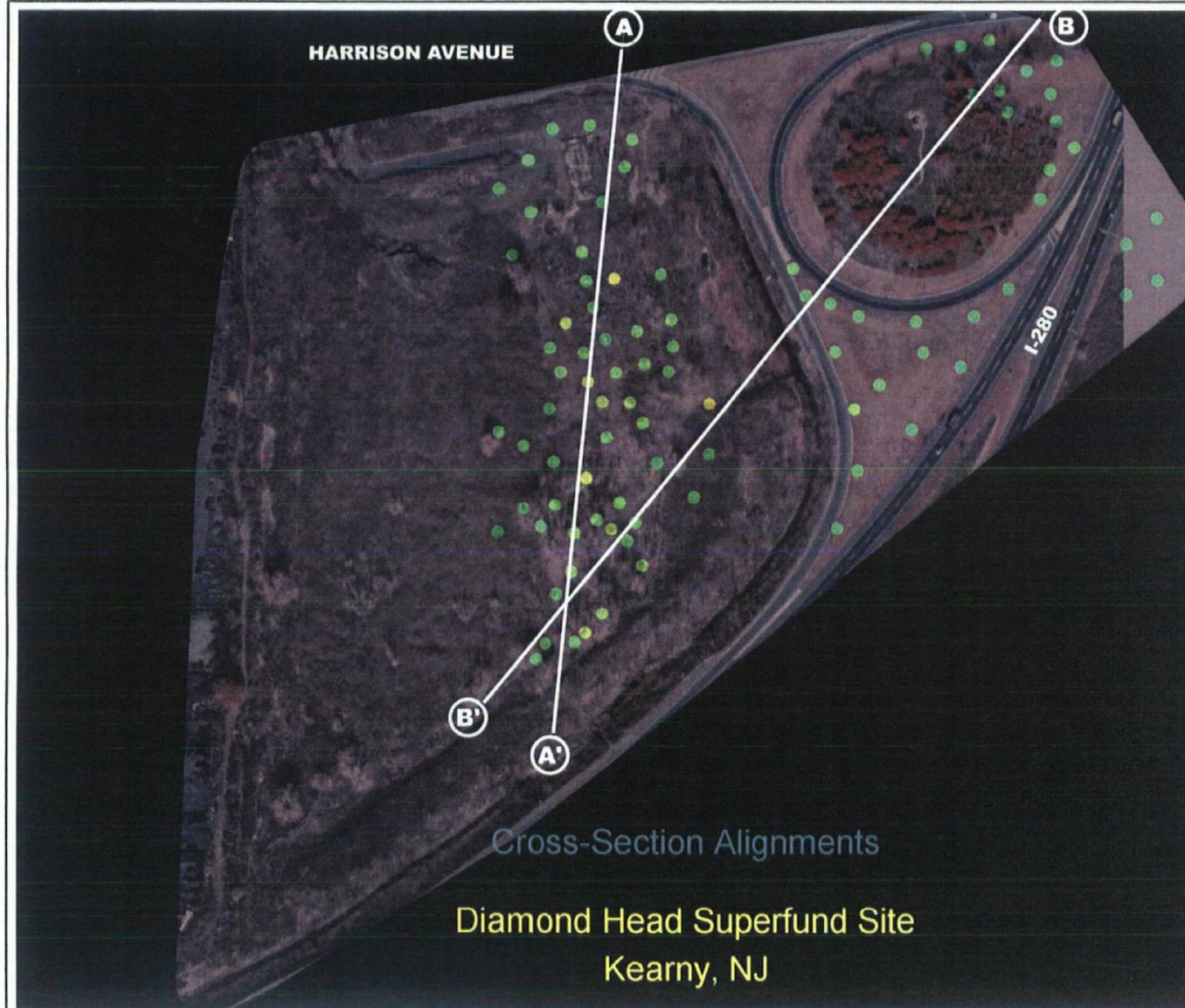
Date & Time:
2008-03-05 10:58 EST



 DAKOTA TECHNOLOGIES FARGO, ND 701.237.4908 WWW.DAKOTATECHNOLOGIES.COM	LIF-001		UVOST By Dakota www.DakotaTechnologies.com
	Site: Diamond Head Superfund	Latitude / Datum: Unavailable / NA	Final depth: 16.92 ft
	Client: CH2M Hill	Longitude / Fix: Unavailable / NA	Max signal: 58.0 % @ 6.18 ft
	Job: 359471.03.02.01	Operator/Unit: T.Rudolph/LAB01	Date & Time: 2008-03-04 13:02 EST



 DAKOTA TECHNOLOGIES FARGO, ND 701.237.4908 WWW.DAKOTATECHNOLOGIES.COM	LIF-007B		UVOST By Dakota www.DakotaTechnologies.com
	Site: Diamond Head Superfund	Latitude / Datum: Unavailable / NA	Final depth: 14.50 ft
	Client: CH2M Hill	Longitude / Fix: Unavailable / NA	Max signal: 169.8 % @ 6.22 ft
	Job: 359471.03.02.01	Operator/Unit: T.Rudolph/LAB01	Date & Time: 2008-03-05 10:25 EST



HARRISON AVENUE

I-280

Cross-Section Alignments

Diamond Head Superfund Site
Kearny, NJ



LEGEND

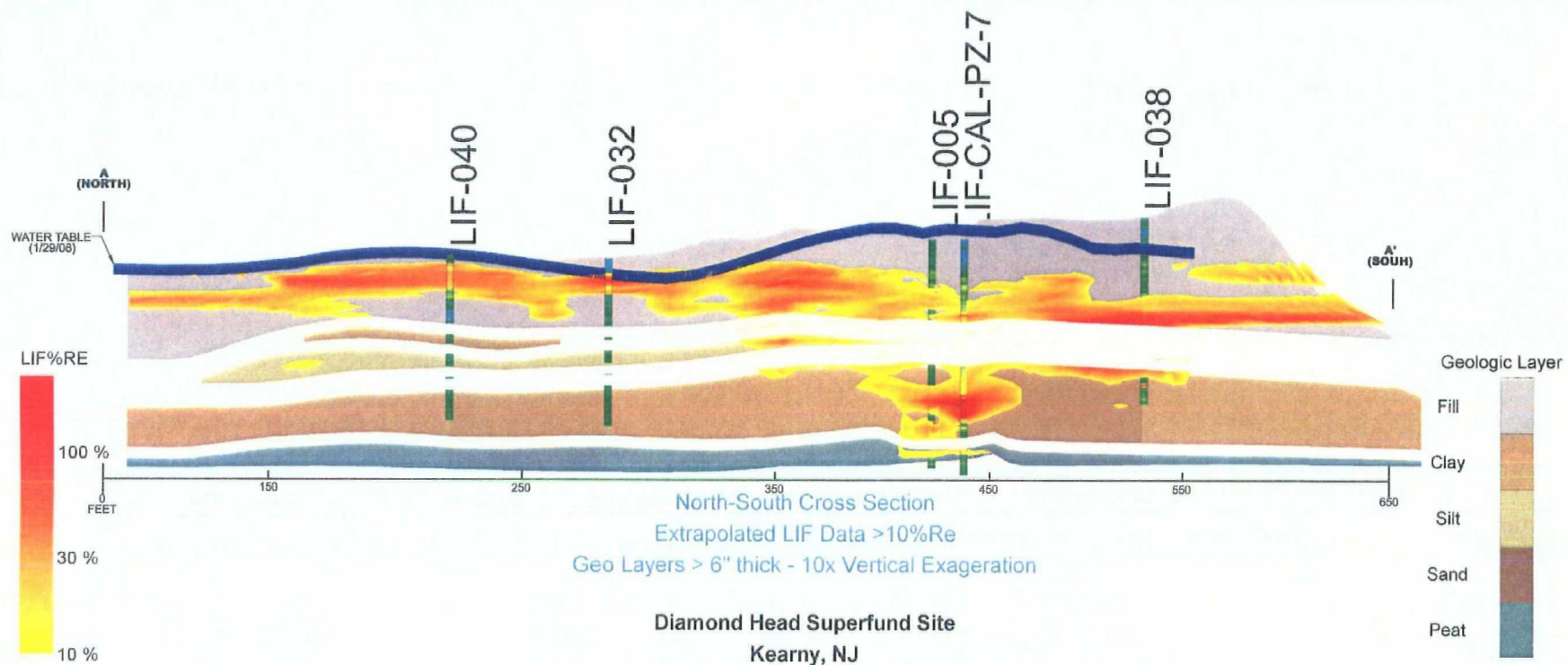
● Laser Induced Fluorescence (LIF)
Boring Location

A — A' Cross Section Line

Not to Scale

Figure 4-4
Cross Section Location Map
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL

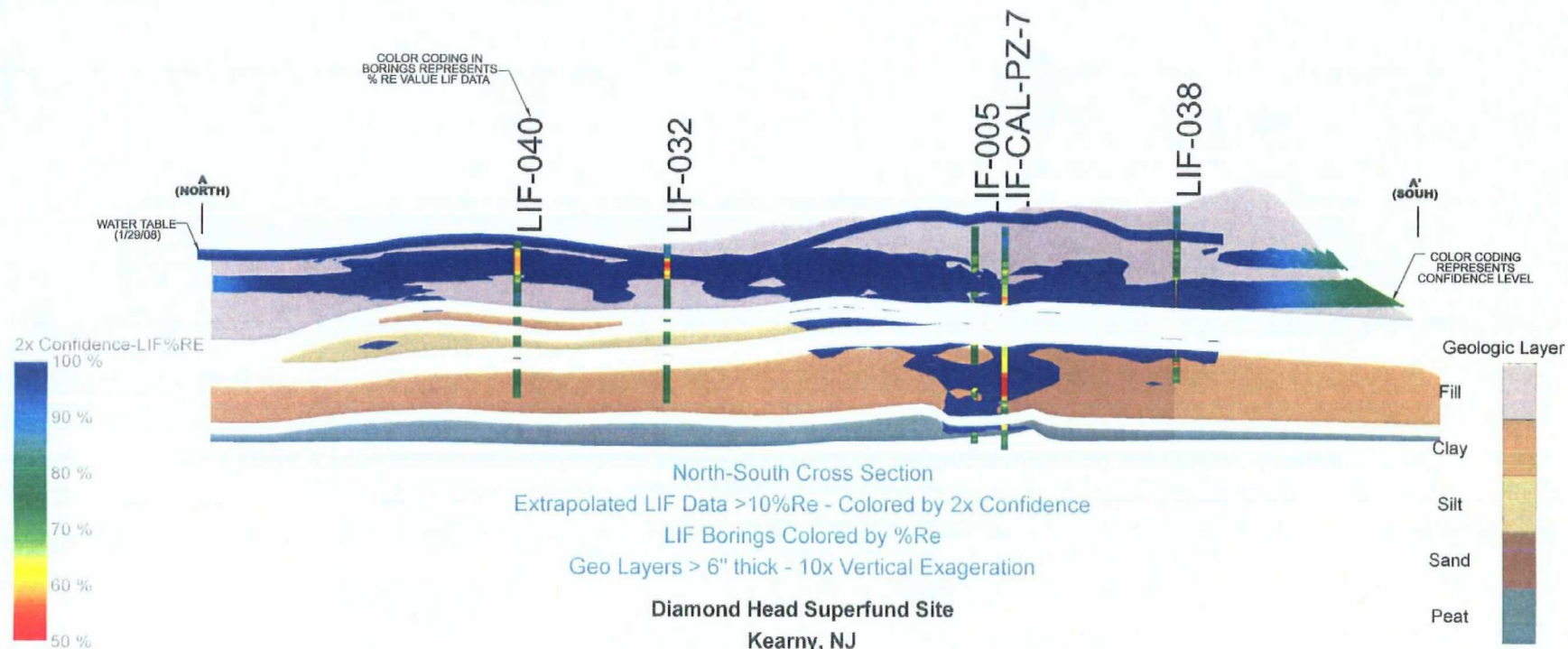


GENERAL NOTES

1. THIS FIGURE SHOWS THE APPROXIMATE DISTRIBUTION OF LNAPL IN THE SUBSURFACE BASED ON MATHEMATICAL MODELS OF THE LIF DATA. COLOR CODING REPRESENTS THE TIME RESPONSE OF THE LIF DATA.
2. GEOLOGIC CONTACTS ARE ESTIMATED OR INFERRRED.
3. SCALE IS APPROXIMATE.
4. GEOLOGIC LAYERS ARE SHOWN IN "EXPLODED VIEW" TO ACCENTUATE LNAPL DATA.

Figure 4-5
Cross Section A - A' of LNAPL
Distribution Based on LIF Data
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL

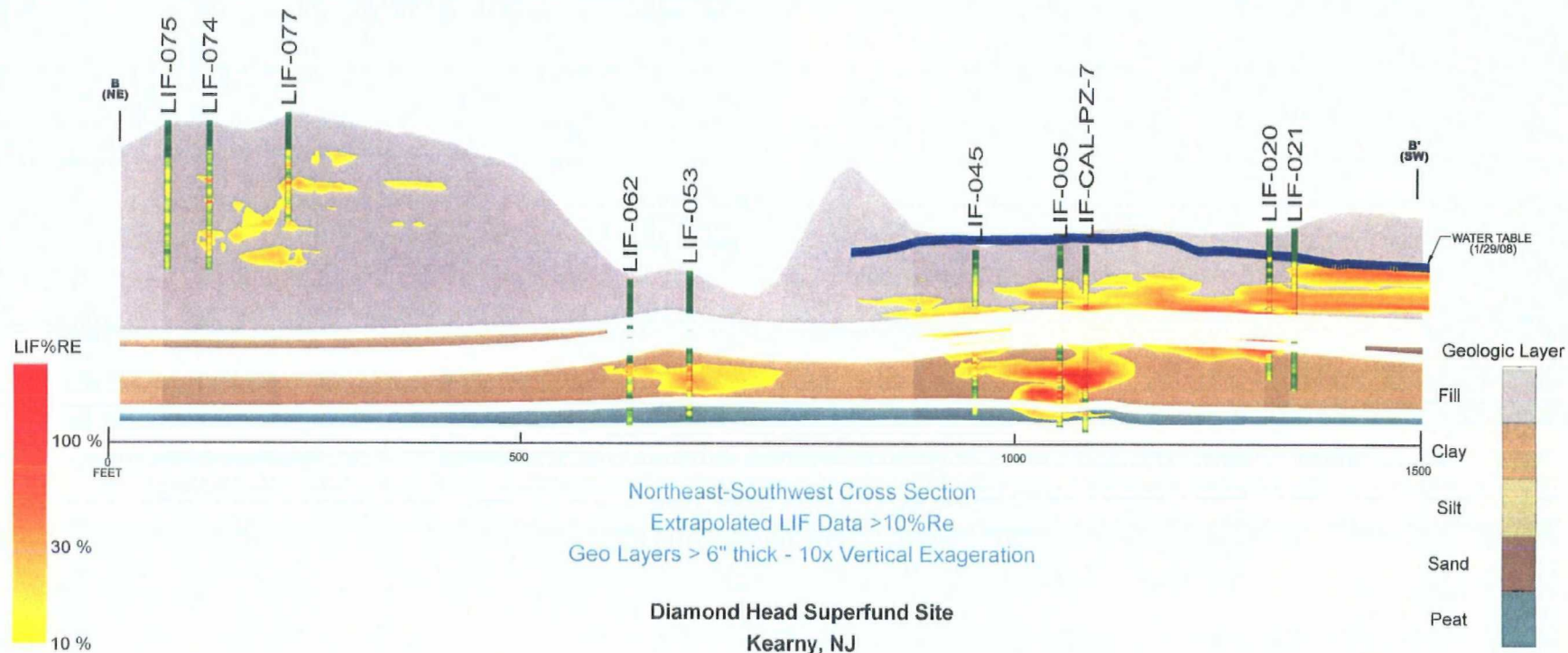


GENERAL NOTES

1. THIS FIGURE SHOWS THE CONFIDENCE LEVEL IN THE EXTRAPOLATED DATA. USED FOR THE CORRESPONDING CROSS-SECTION. COLOR CODING IN THE LIF BORING LOCATIONS REPRESENTS ACTUAL NIS DATA. COLOR CODING IN THE LIF MASS REPRESENTS THE CONFIDENCE LEVEL THAT THE PROBABILITY OF THE EXTRAPOLATED DATA IS WITHIN ± TWO TIMES THE INDICATED NIS VALUE. DARKER BLUE INDICATES HIGHER CONFIDENCE IN THE DATA.
2. GEOLOGIC CONTACTS ARE ESTIMATED OR INFERRED.
3. SCALE IS APPROXIMATE.
4. GEOLOGIC LAYERS ARE SHOWN IN "EXPLODED VIEW" TO ACCENTUATE LIF DATA.

Figure 4-5A
Data Confidence Evaluation
for Cross Section A - A'
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL

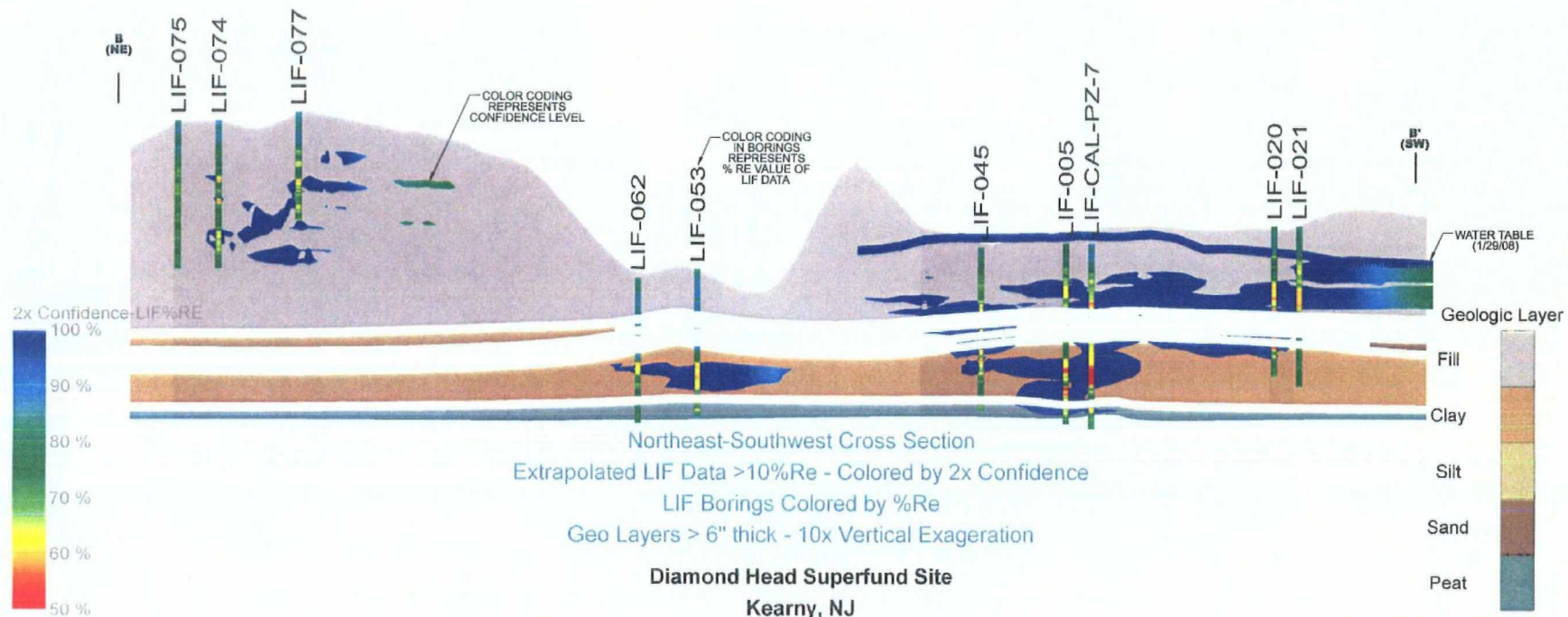


GENERAL NOTES

1. THIS FIGURE SHOWS THE APPROXIMATE DISTRIBUTION OF LNAPL IN THE SUBSURFACE BASED ON MATHEMATICAL MODELING OF THE LIF DATA. COLOR CODING REPRESENTS THE TIME RESPONSE OF THE LIF DATA.
2. GEOLOGIC CONTACTS ARE ESTIMATED OR INFERRED.
3. SCALE IS APPROXIMATE.
4. GEOLOGIC LAYERS ARE SHOWN IN "EXPLODED VIEW" TO ACCOMMODATE LNAPL DATA.

Figure 4-6
Cross Section B - B' of LNAPL
Distribution Based on LIF Data
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL



GENERAL NOTES

1. THIS FIGURE SHOWS THE CONFIDENCE LEVEL IN THE KNOWN DATA USED FOR THE CORRESPONDING CROSS-SECTION. COLOR CODING IN THE LIF BORING LOCATION REPRESENTS ACTUAL %RE DATA. COLOR CODING IN THE LIMP-045 REPRESENTS THE CONFIDENCE LEVEL THAT THE PROBABILITY OF THE EXTRAPOLATED DATA IS WITHIN +/- TWO TIMES THE INDICATED %RE VALUE. DARKER BLUE INDICATES HIGHER CONFIDENCE IN THE DATA.
2. GEOLOGIC CONTACTS ARE ESTIMATED OR INFERRRED.
3. SCALE IS APPROXIMATE.
4. GEOLOGIC LAYERS ARE SHOWN IN "EXPLODED VIEW" TO ACCENTUATE LIMP-045 DATA.

Figure 4-6A
Data Confidence Evaluation
for Cross Section B - B'
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL

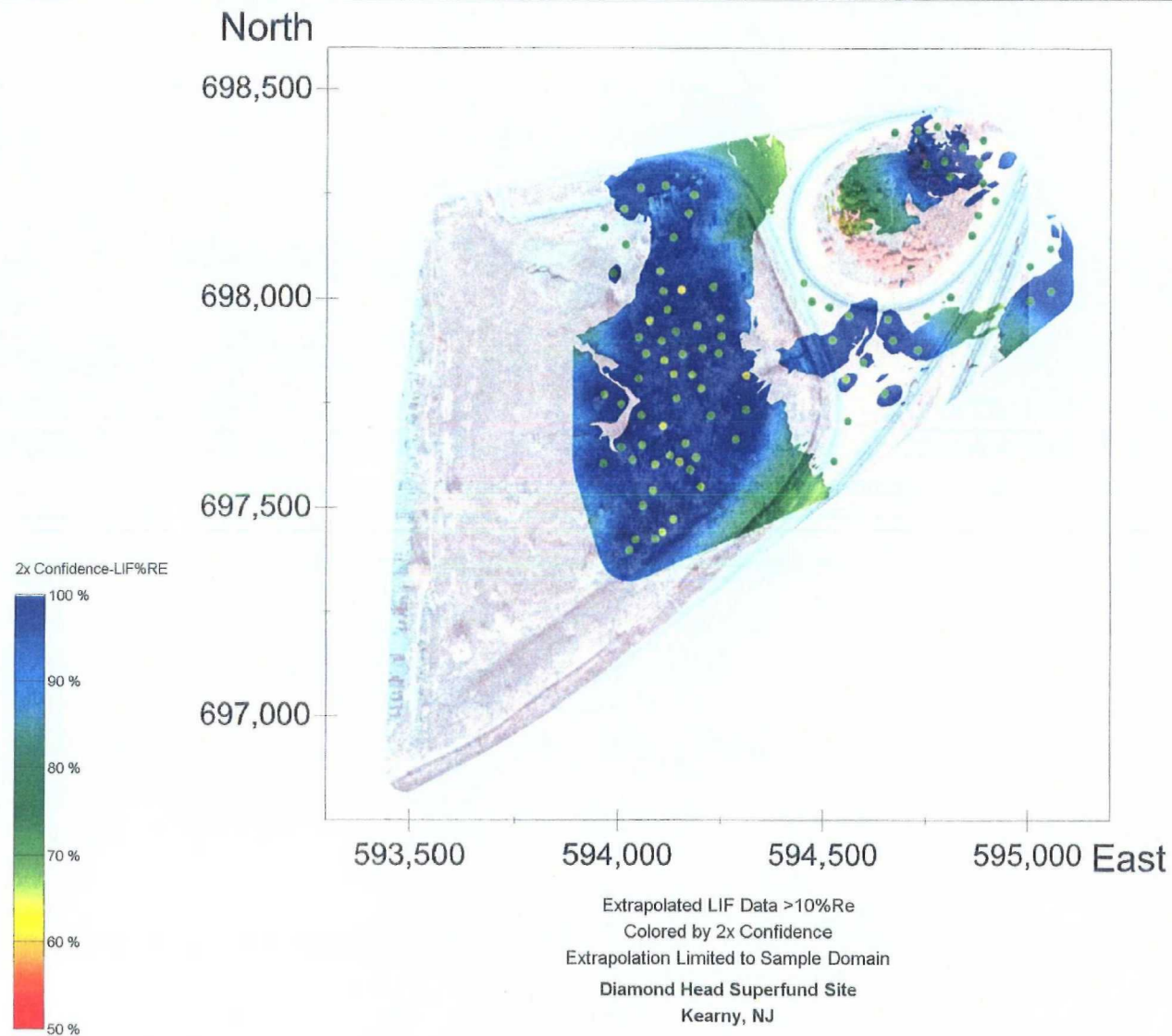


GENERAL NOTES

THIS FIGURE SHOWS THE APPROXIMATE DISTRIBUTION OF LNAPL IN THE SUBSURFACE BASED ON MATHEMATICAL KRIGING OF THE LIF DATA. COLOR CODING REPRESENTS THE %RE RESPONSE OF THE LIF DATA.

Figure 4-7
Lateral Extent of LNAPL,
LIF > 10% RE
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL

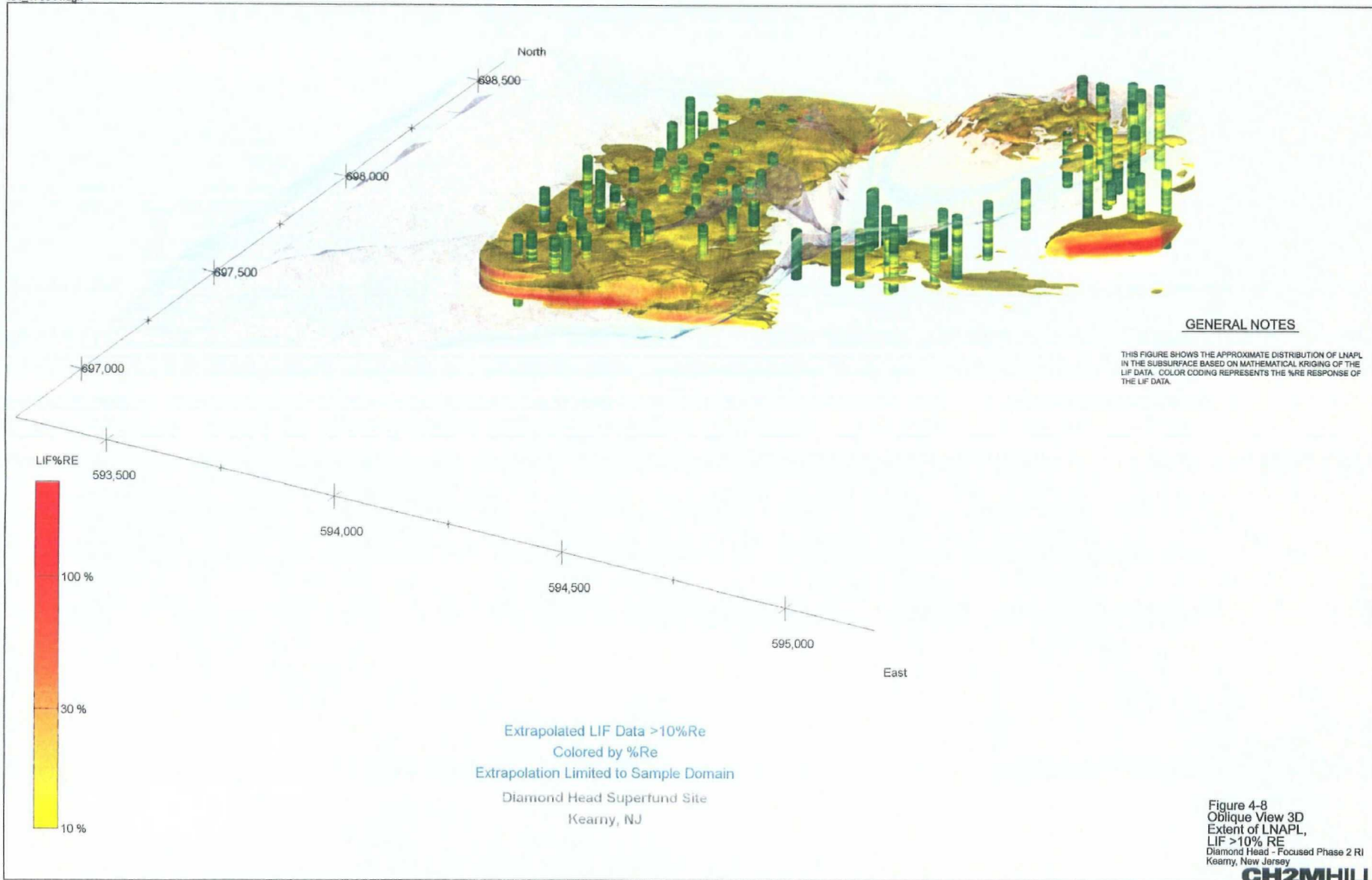


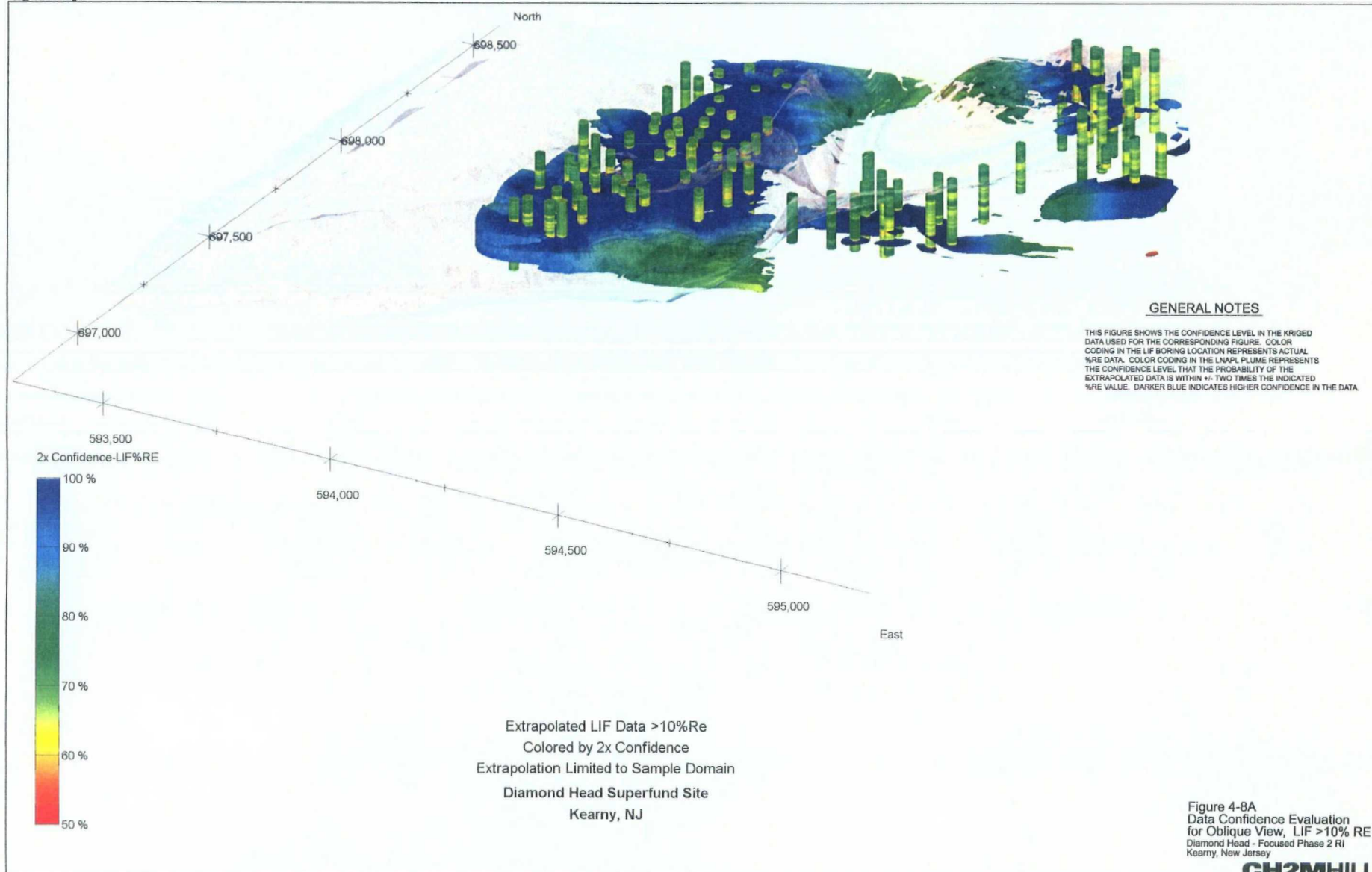
GENERAL NOTES

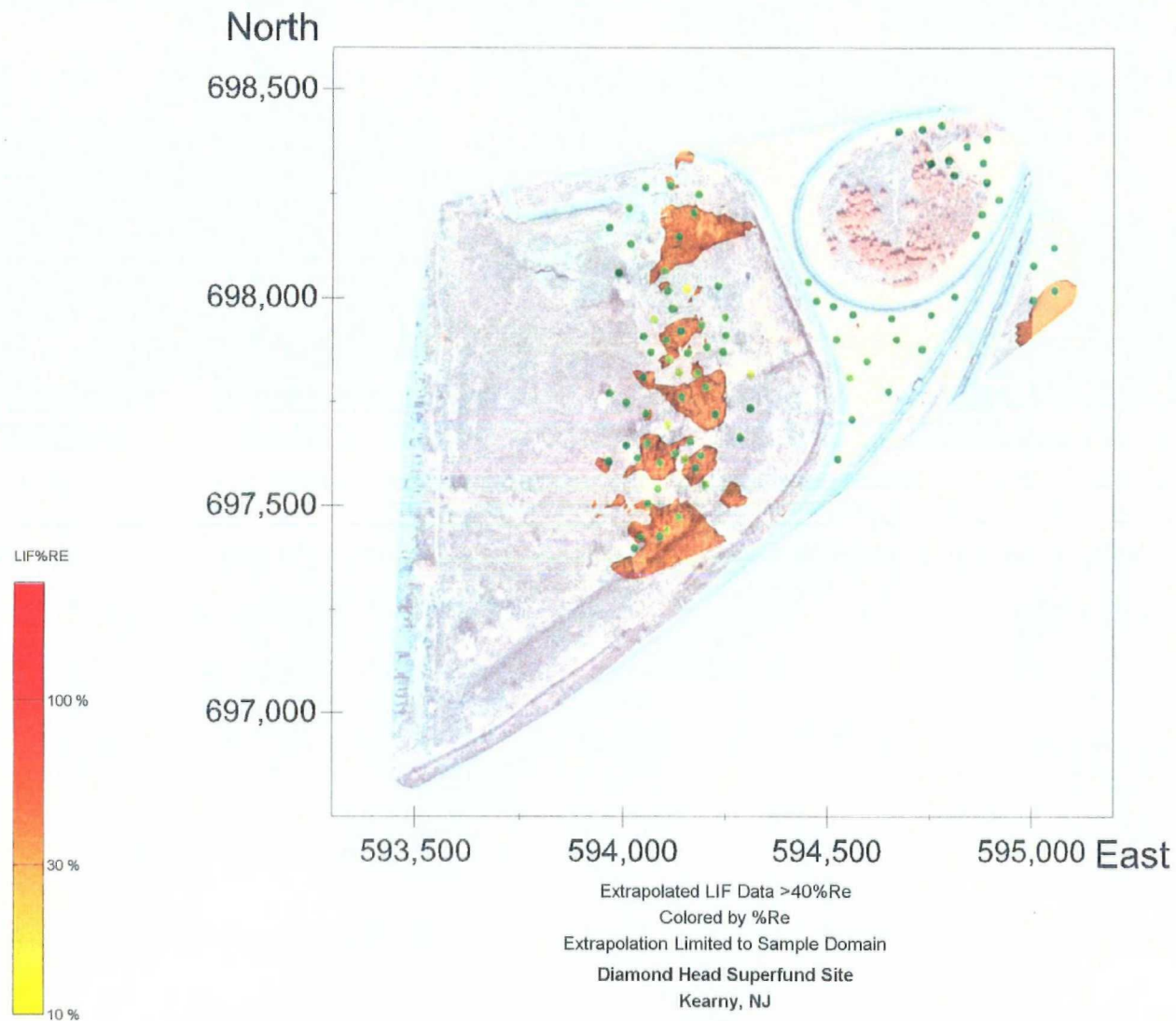
THIS FIGURE SHOWS THE CONFIDENCE LEVEL IN THE KRIGED DATA USED FOR THE CORRESPONDING FIGURE. COLOR CODING IN THE LIF BORING LOCATION REPRESENTS ACTUAL %RE DATA. COLOR CODING IN THE LNAPL PLUME REPRESENTS THE CONFIDENCE LEVEL THAT THE PROBABILITY OF THE EXTRAPOLATED DATA IS WITHIN +/- TWO TIMES THE INDICATED %RE VALUE. DARKER BLUE INDICATES HIGHER CONFIDENCE IN THE DATA.

Figure 4-7A
Data Confidence Evaluation
for Lateral Extent of
LNAPL LIF >10% RE
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL





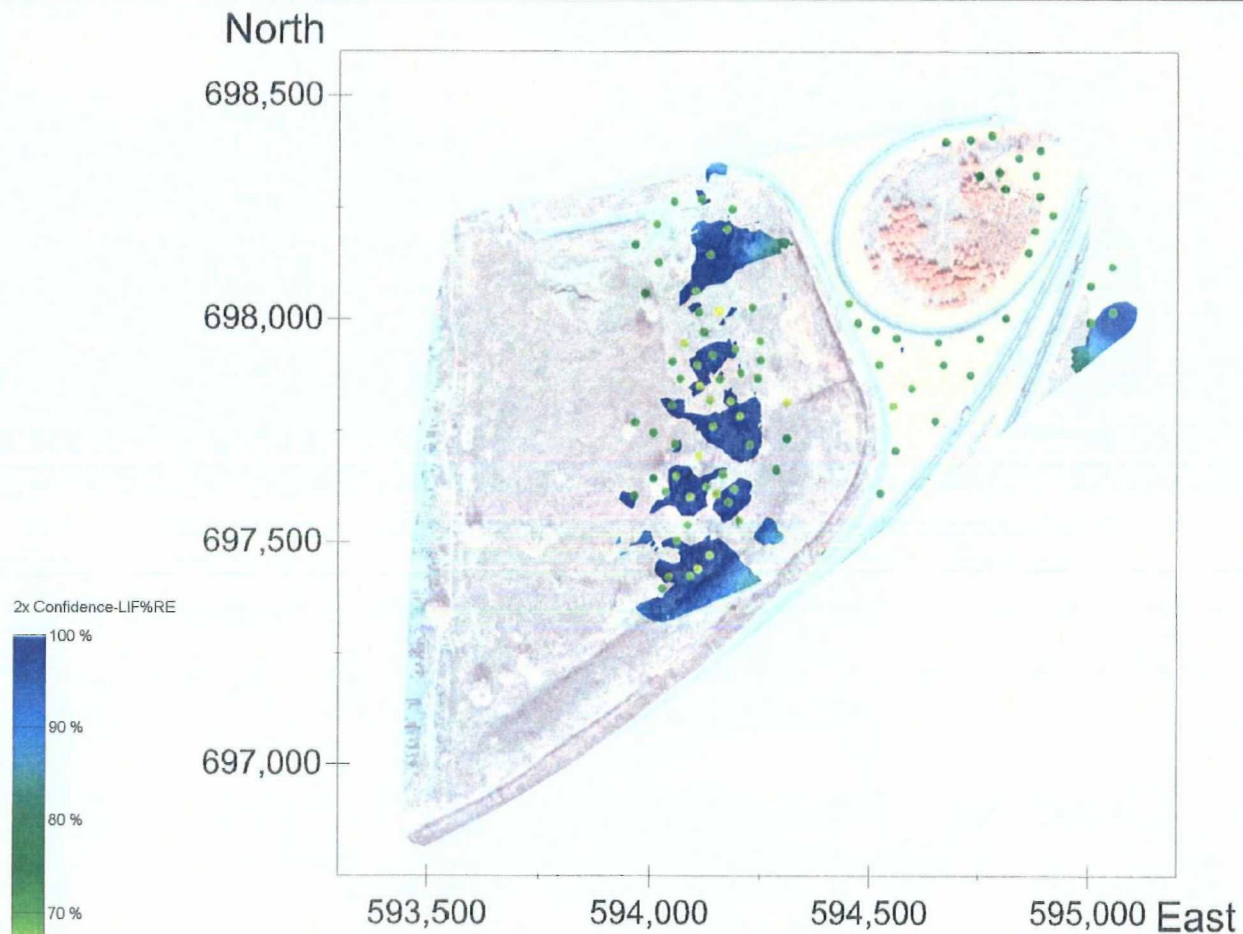


GENERAL NOTES

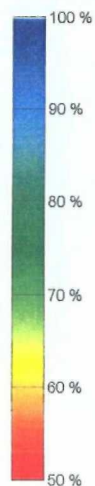
THIS FIGURE SHOWS THE APPROXIMATE DISTRIBUTION OF LNAPL IN THE SUBSURFACE BASED ON MATHEMATICAL KRIGING OF THE LIF DATA. COLOR CODING REPRESENTS THE %RE RESPONSE OF THE LIF DATA.

Figure 4-9
Lateral Extent of LNAPL,
LIF >40% RE
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

CH2MHILL



2x Confidence-LIF%RE



Extrapolated LIF Data >40%Re
Colored by 2x Confidence
Extrapolation Limited to Sample Domain
Diamond Head Superfund Site
Kearny, NJ

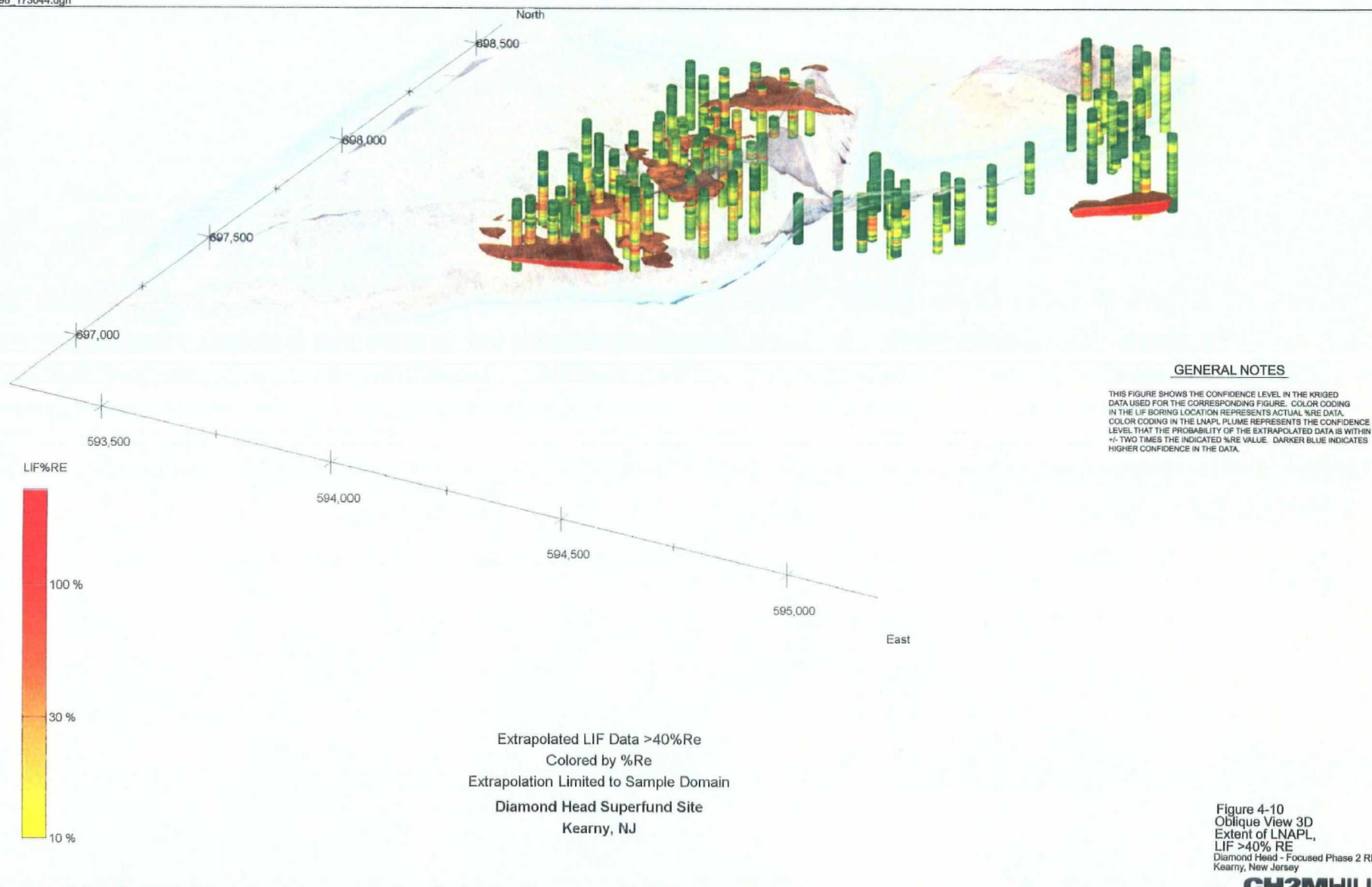
GENERAL NOTES

THIS FIGURE SHOWS THE CONFIDENCE LEVEL IN THE KRIGED DATA USED FOR THE CORRESPONDING FIGURE. COLOR CODING IN THE LIF BORING LOCATION REPRESENTS ACTUAL %RE DATA. COLOR CODING IN THE LNAPL PLUME REPRESENTS THE CONFIDENCE LEVEL THAT THE PROBABILITY OF THE EXTRAPOLATED DATA IS WITHIN +/- TWO TIMES THE INDICATED %RE VALUE. DARKER BLUE INDICATES HIGHER CONFIDENCE IN THE DATA.

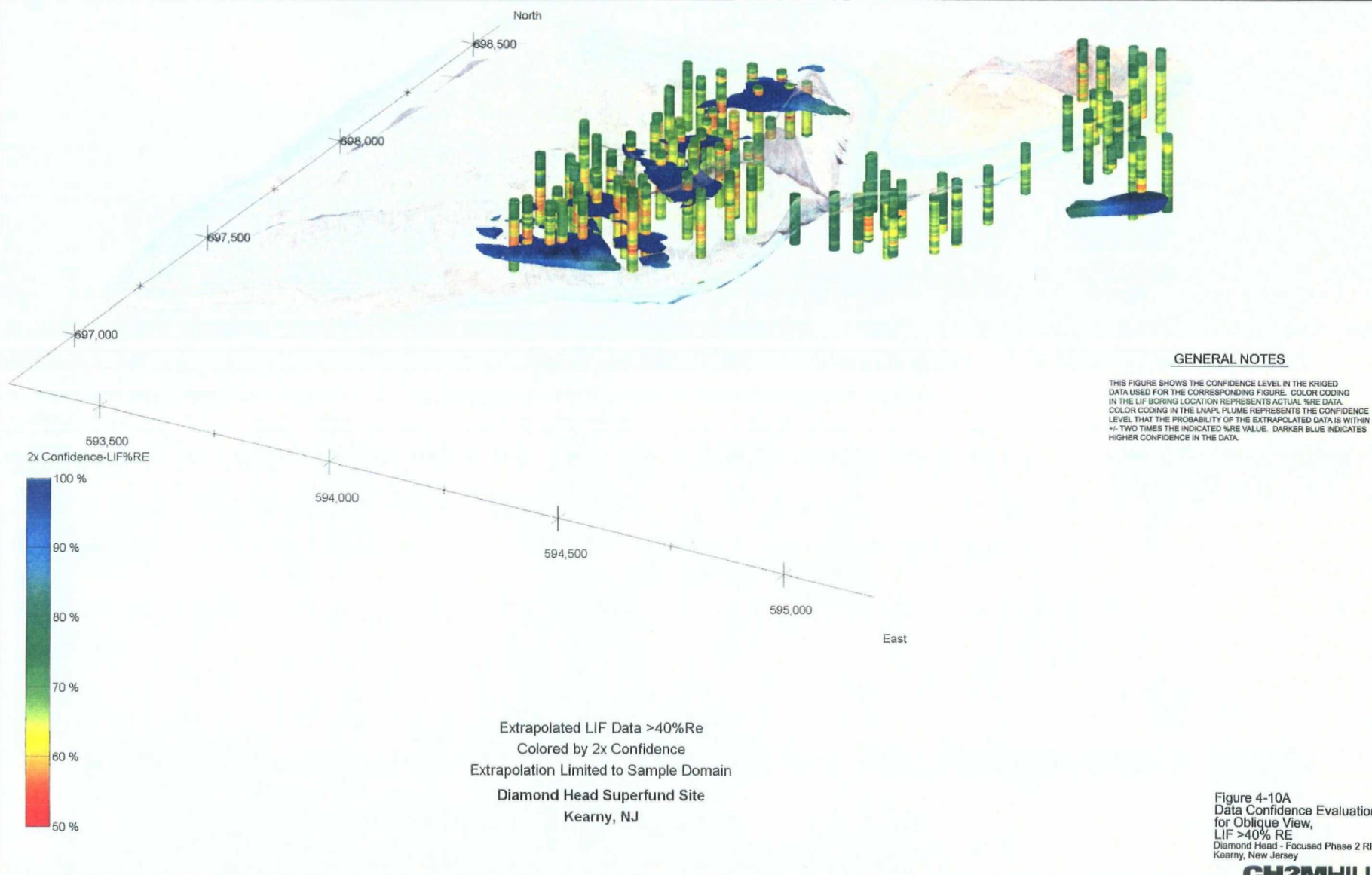
Figure 4-9A
Data Confidence Evaluation
for Lateral Extent of
LNAPL LIF >40% RE
Diamond Head - Focused Phase 2 RI
Kearny, New Jersey

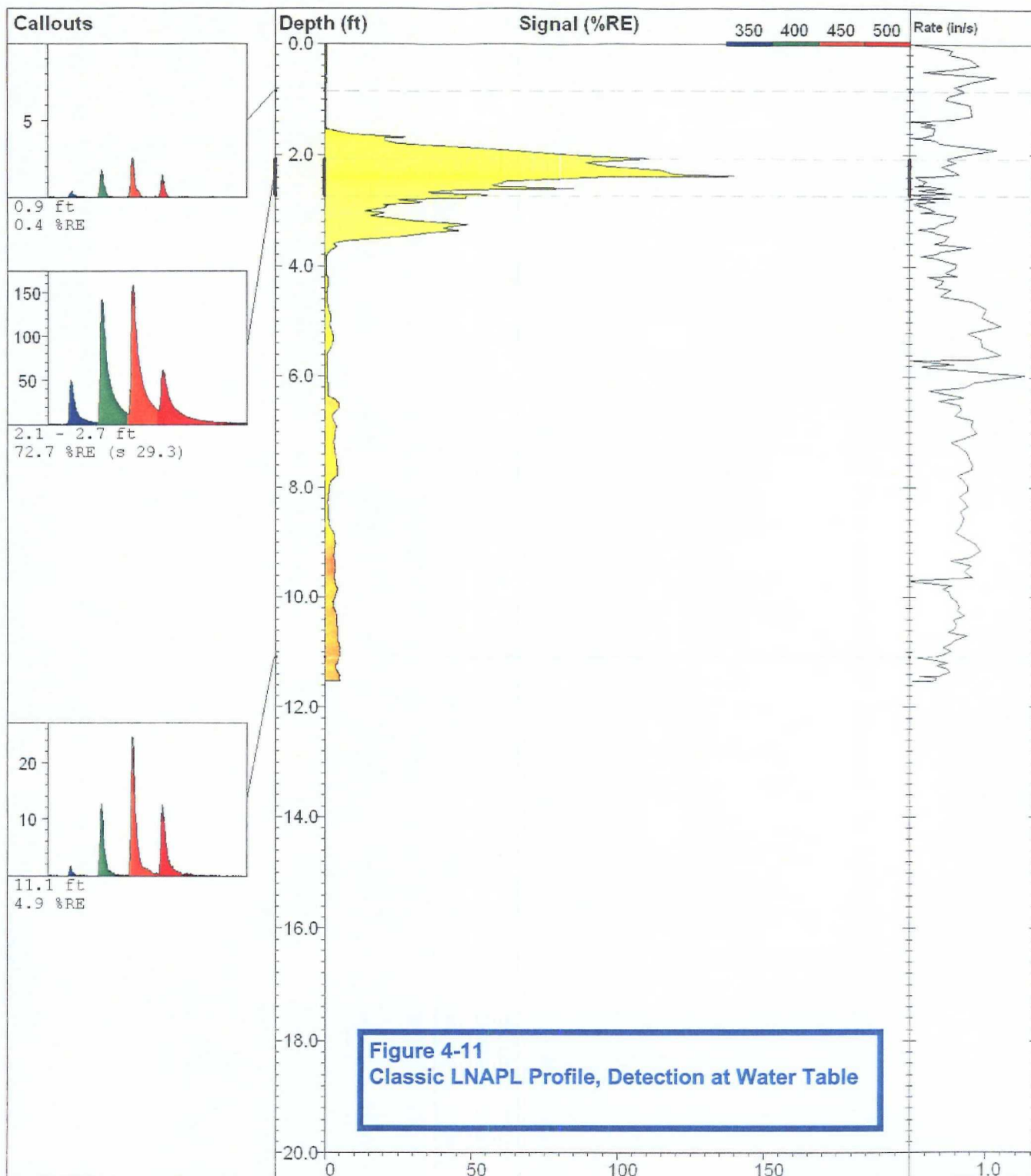
CH2MHILL

f98_173044.dgn



CH2MHILL





LIF-032

Site:
Diamond Head Superfund

Client:
CH2M Hill

Job:
359471.03.02.01

Latitude / Datum:
Unavailable / NA

Longitude / Fix:
Unavailable / NA

Operator/Unit:
T.Rudolph/LAB01

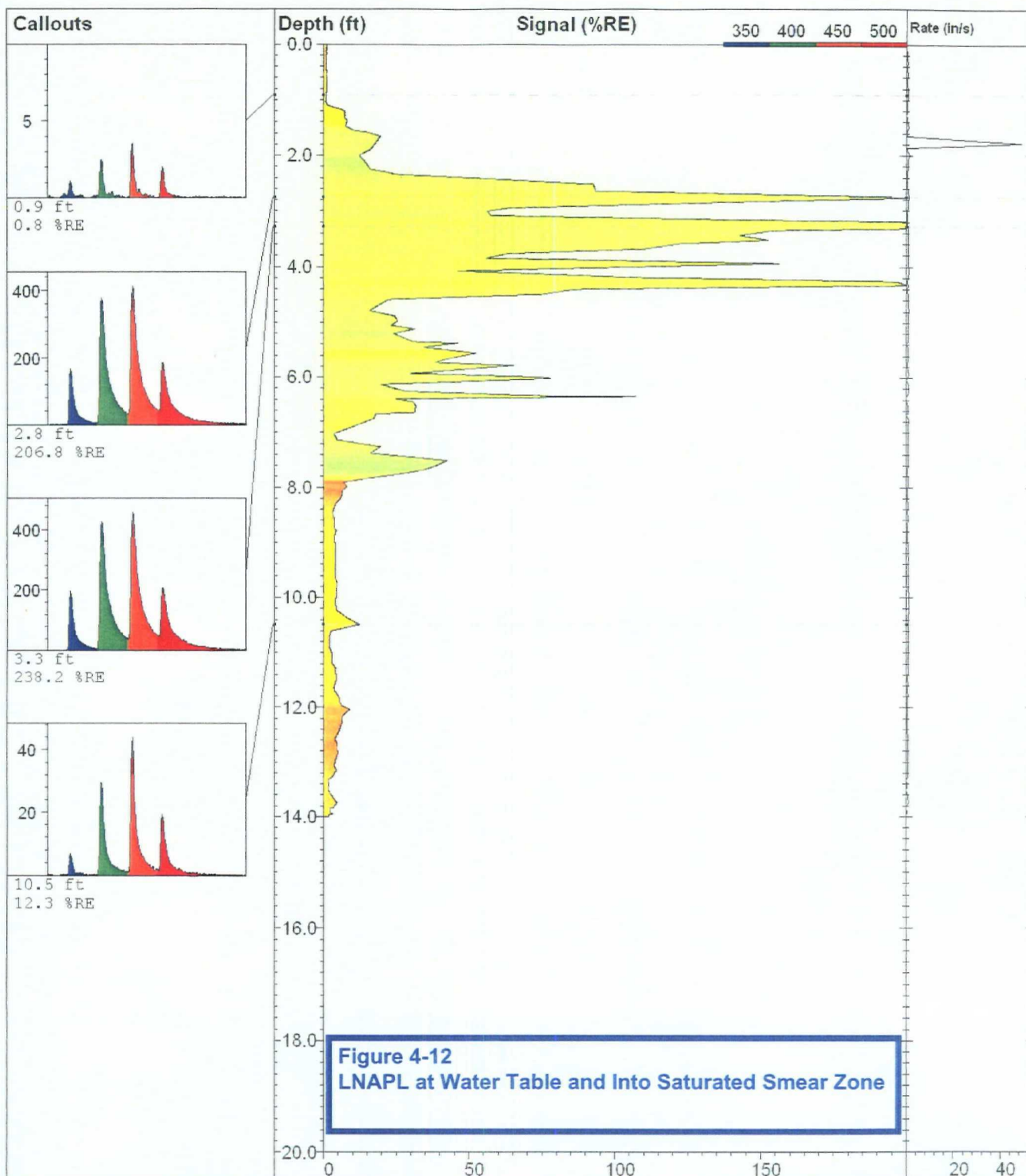
UVOST By Dakota

www.DakotaTechnologies.com

Final depth:
11.52 ft

Max signal:
140.8 % @ 2.38 ft

Date & Time:
2008-03-10 10:02 EDT



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TECHNOLOGIES**

FARGO, ND 701.237.4908
WWW.DAKOTATECHNOLOGIES.COM

LIF-012

Site:
Diamond Head Superfund

Client:
CH2M Hill

Job:
359471.03.02.01

Latitude / Datum:
Unavailable / NA

Longitude / Fix:
Unavailable / NA

Operator/Unit:
T.Rudolph/LAB01

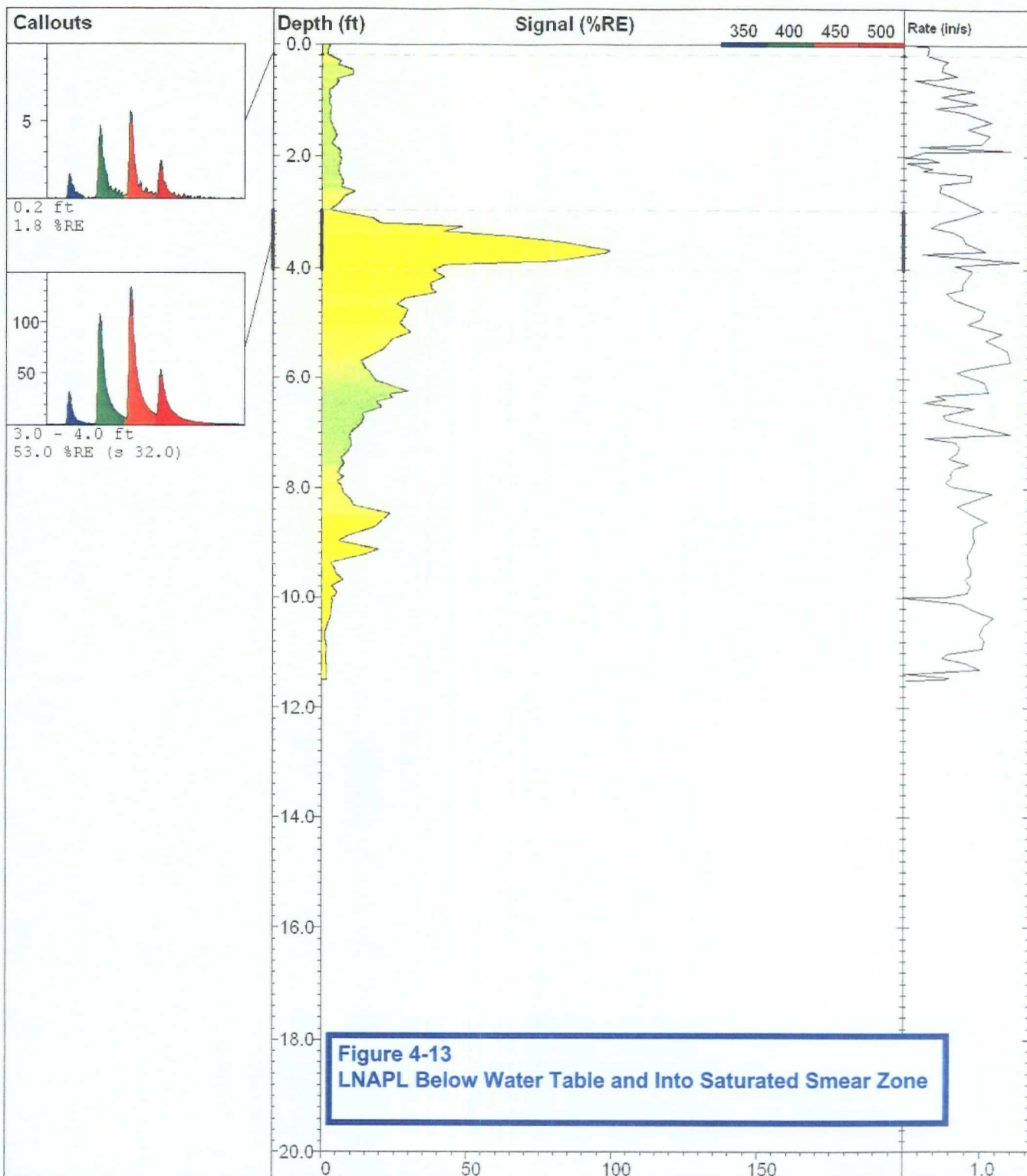
UVOST By Dakota


www.DakotaTechnologies.com

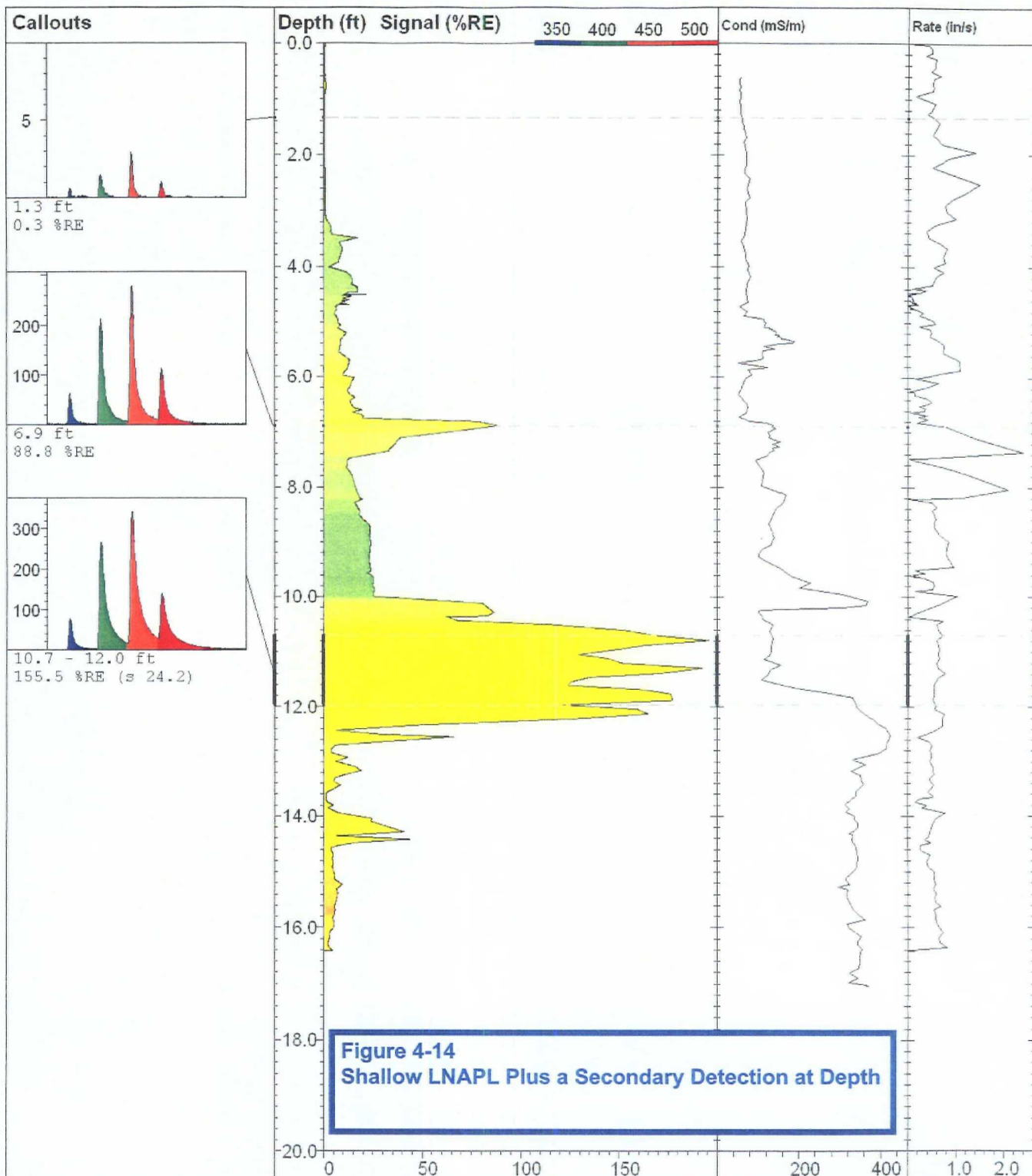
Final depth:
14.00 ft


Max signal:
238.2 % @ 3.29 ft

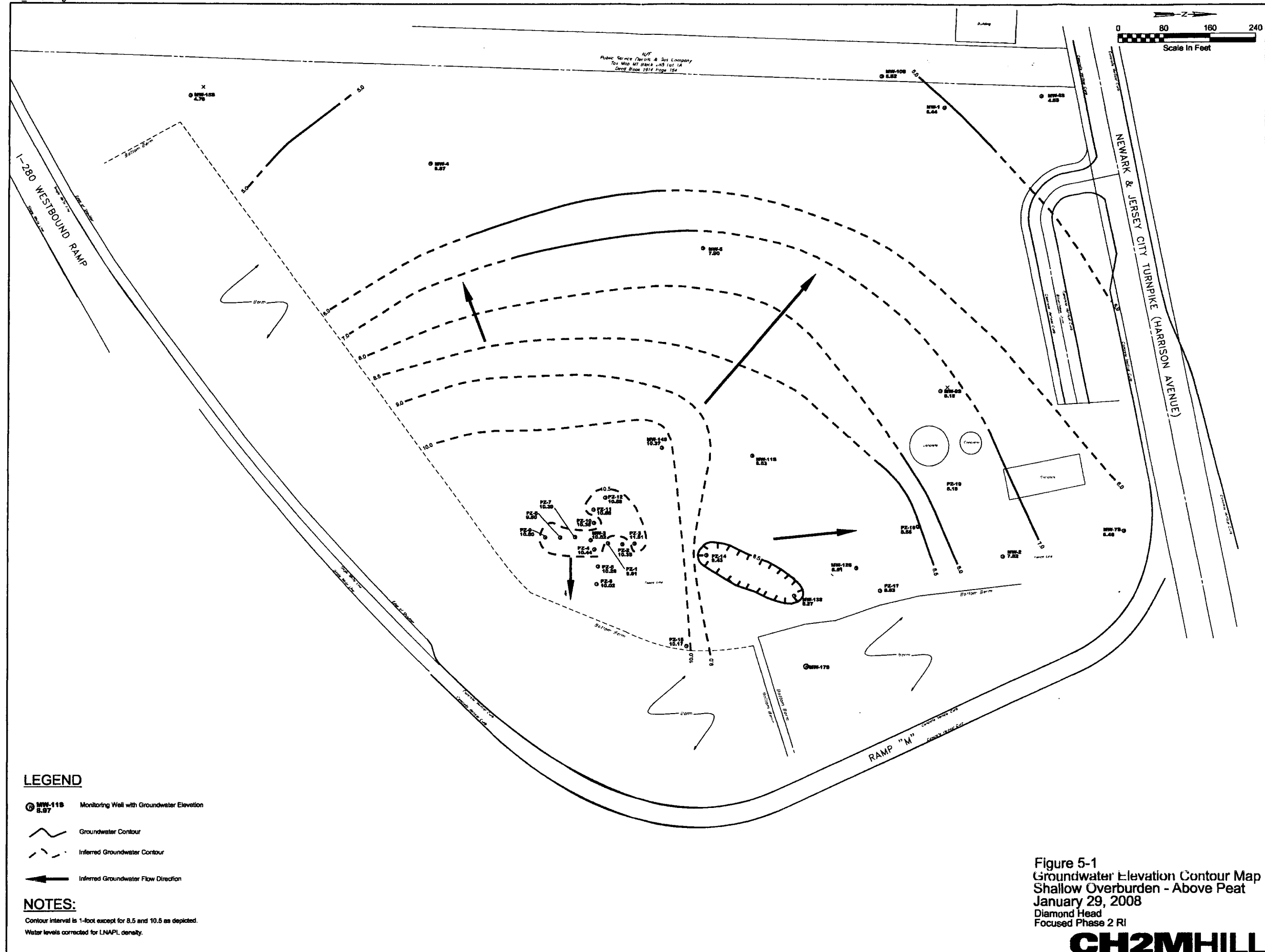
Date & Time:
2008-03-05 13:24 EST

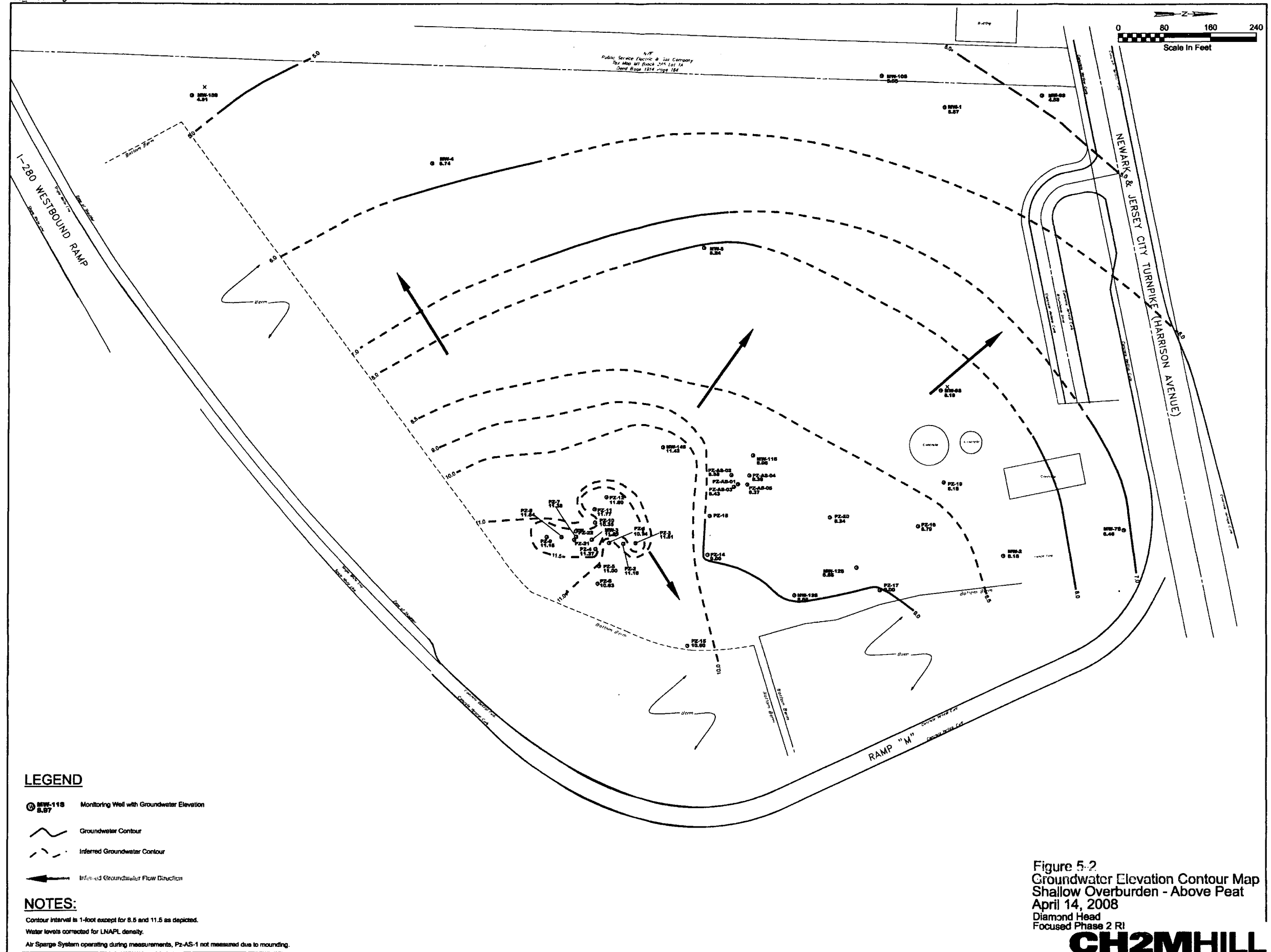


 DAKOTA TECHNOLOGIES FARGO, ND 701.237.4908 WWW.DAKOTATECHNOLOGIES.COM	LIF-034		UVOST By Dakota www.DakotaTechnologies.com		
	Site: Diamond Head Superfund		Latitude / Datum: Unavailable / NA		
	Client: CH2M Hill		Longitude / Fix: Unavailable / NA		
	Job: 359471.03.02.01		Operator/Unit: T.Rudolph/LAB01		
			Final depth: 11.50 ft		
				Max signal: 99.3 % @ 3.68 ft	
				Date & Time: 2008-03-10 10:44 EDT	



 DAKOTA TECHNOLOGIES FARGO, ND 701.237.4908 WWW.DAKOTATECHNOLOGIES.COM	LIF-CAL-PZ-7		UVOST By Dakota www.DakotaTechnologies.com
	Site: Diamond Head Superfund	Latitude / Datum: Unavailable / NA	Final depth: 16.42 ft
	Client: CH2M Hill	Longitude / Fix: Unavailable / NA	Max signal: 195.9 % @ 10.79 ft
	Job: 359471.03.02.01	Operator/Unit: T.Rudolph/LAB01	Date & Time: 2008-03-04 11:37 EST





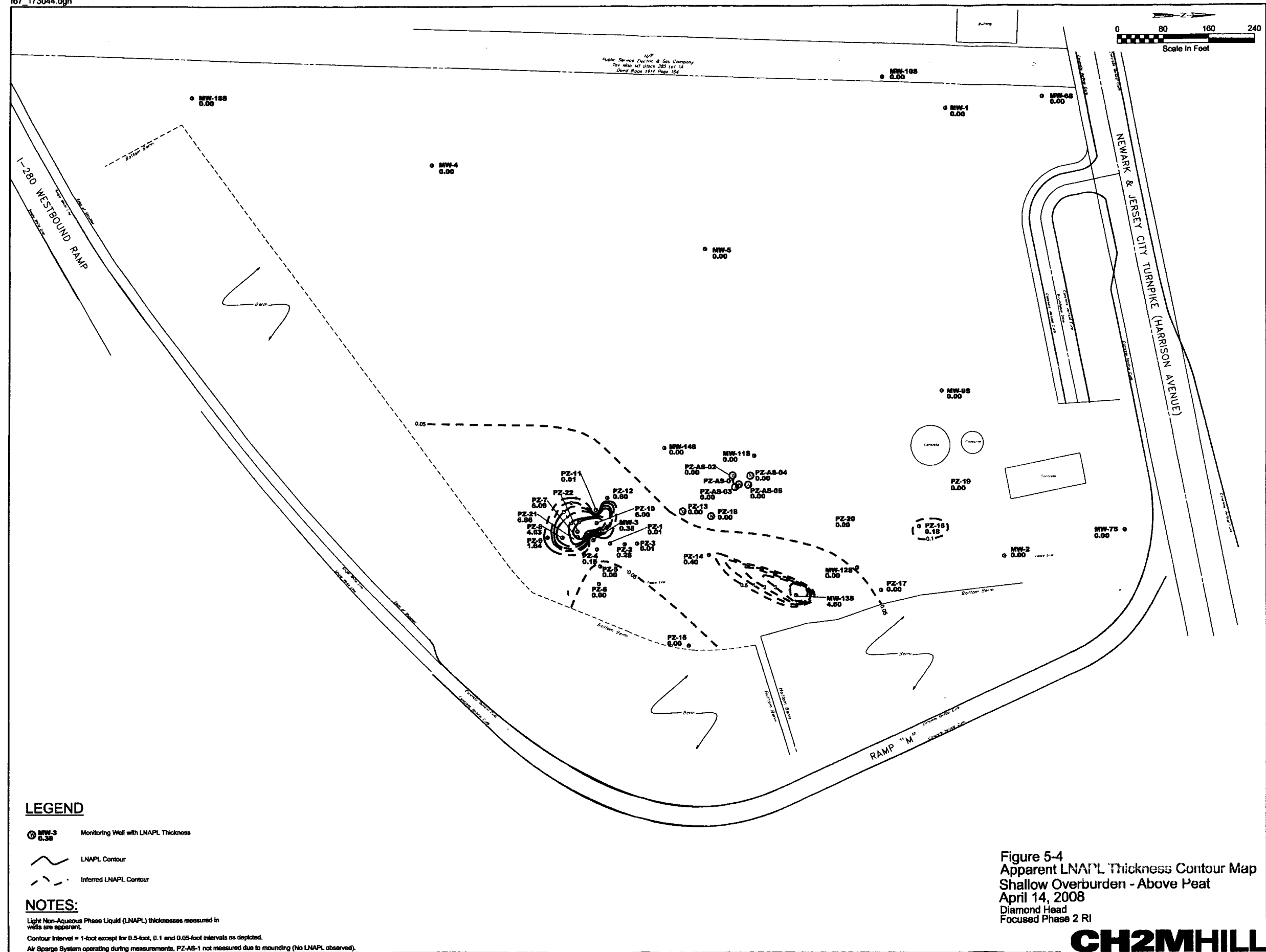


Figure 5-4
Apparent LNAPL Thickness Contour Map
Shallow Overburden - Above Peat
April 14, 2008
Diamond Head
Focused Phase 2 RI

CH2MHILL

FIGURE 6-1
THEORETICAL LNAPL SATURATION VS. HEIGHT ABOVE LNAPL/WATER INTERFACE – LOCATION LIF-PZ7-09-13-2

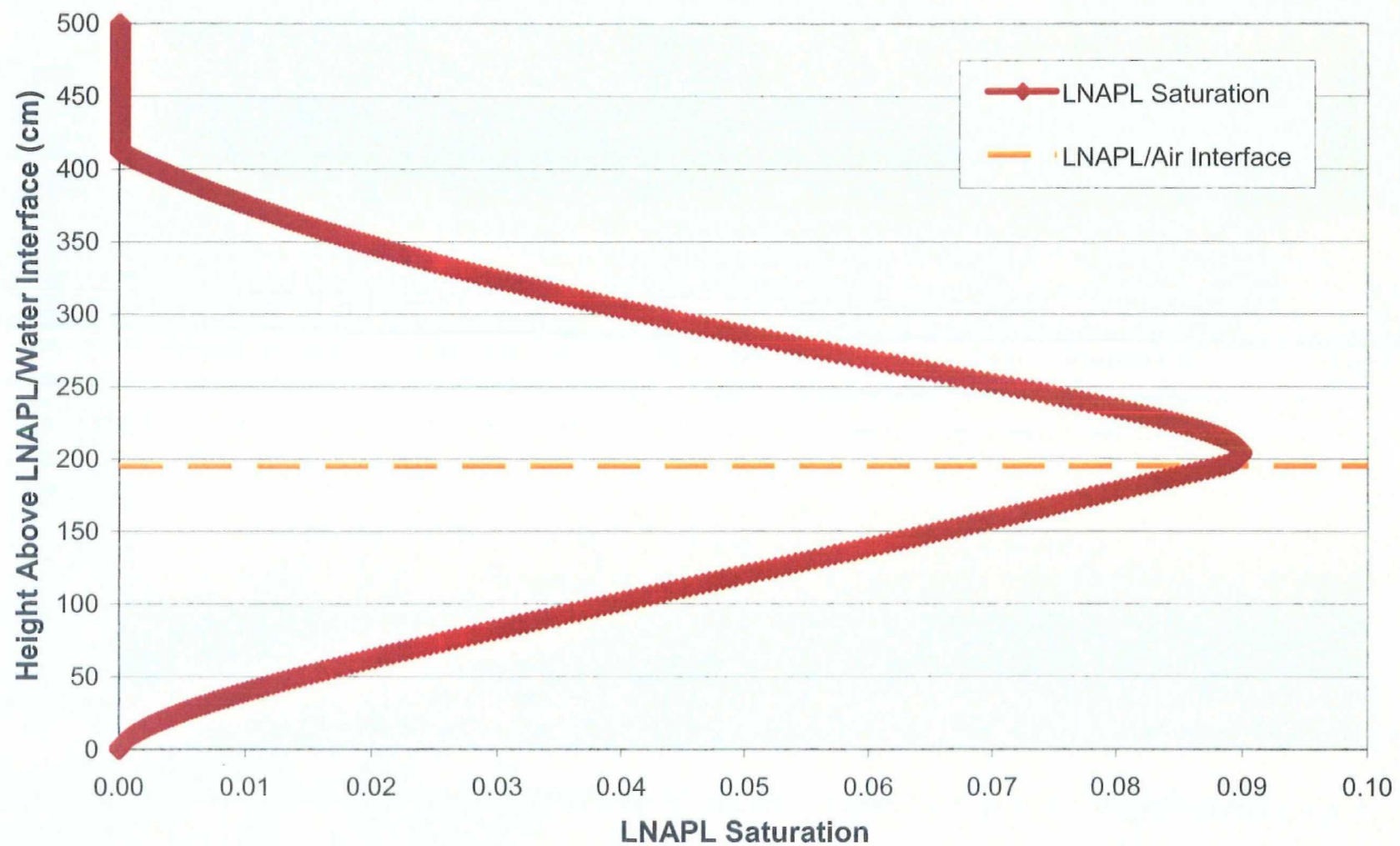
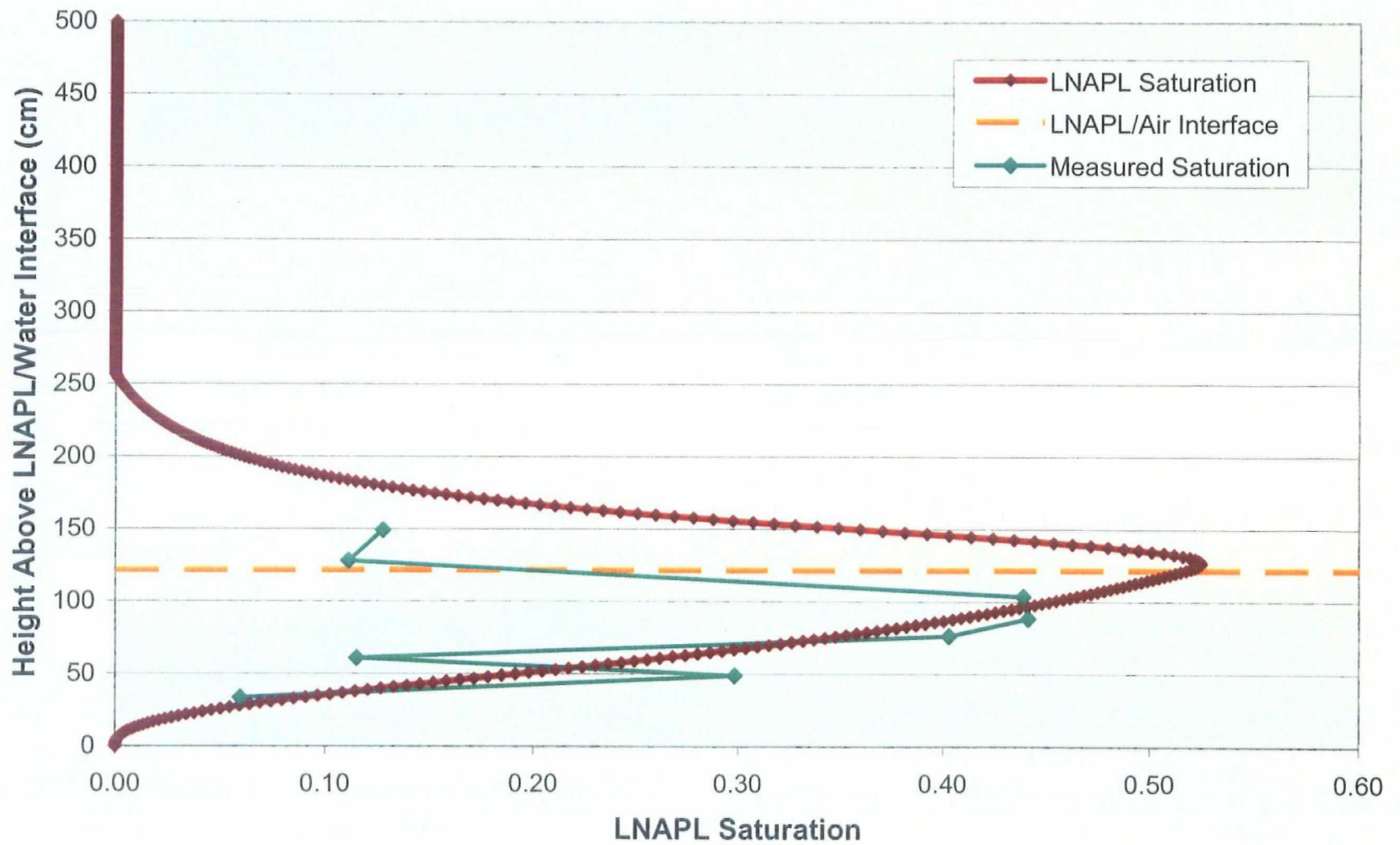
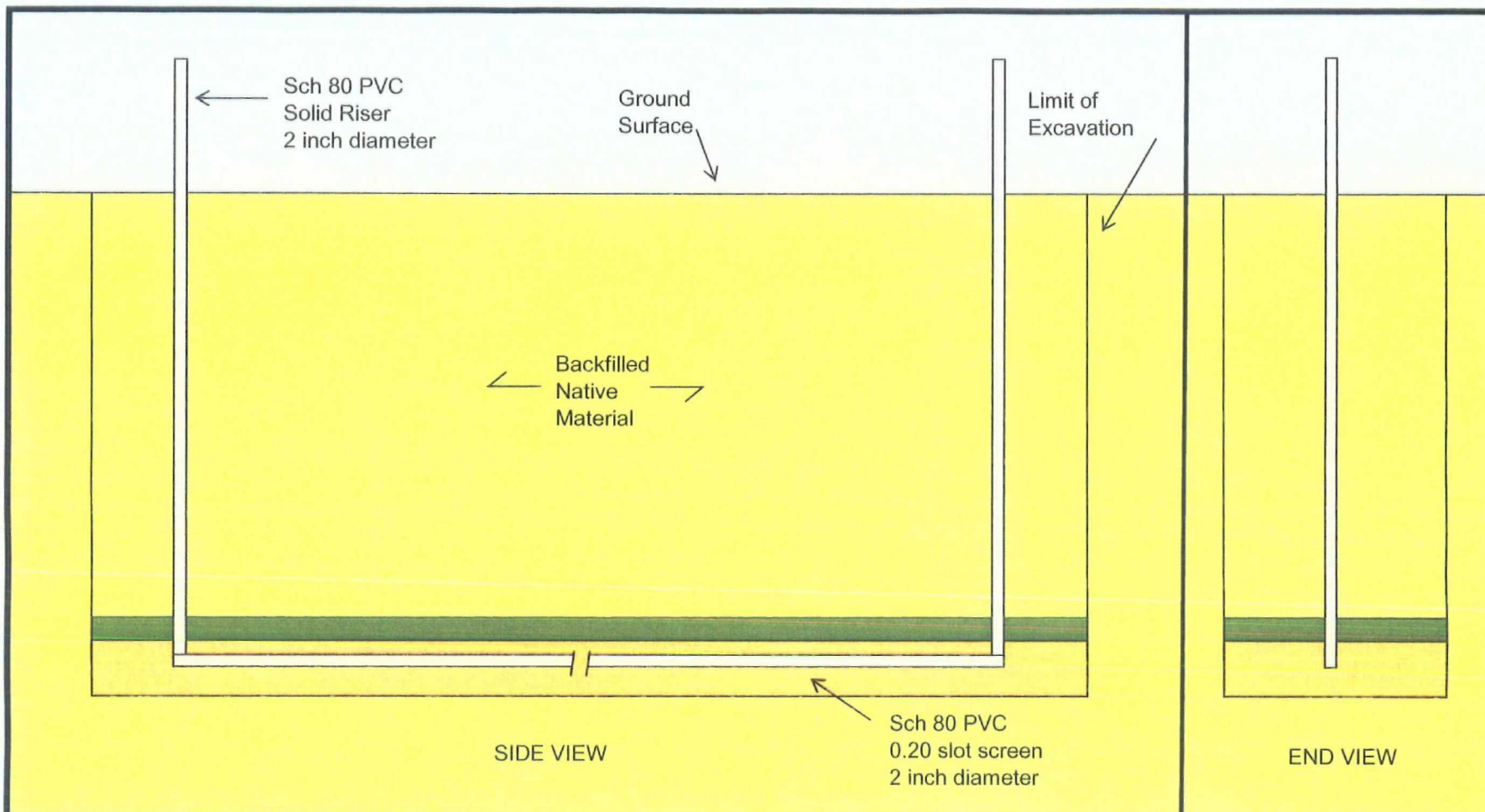


FIGURE 6-2
THEORETICAL LNAPL SATURATION (REFINED) VS. HEIGHT ABOVE LNAPL/WATER INTERFACE – LOCATION LIF-PZ7-09-13-2





- Bentonite
- Sand
- Native Soils

System Dimensions
 Slotted lateral - 30' long x 7' deep
 Pipe - 2 inch diameter, 0.20 slot
 Sand - 18" thick
 Bentonite - 6" thick

Excavation Dimensions
 7-8 feet deep
 32 feet long
 42 inches wide

Lewis Environmental Group
 155 Railroad Plaza
 Royersford, PA 19468

AIR SPARGE PILOT SYSTEM CROSS SECTION
 Based on Drawing Provided by Lewis Environmental Group

Figure 7-1
Air/Bio Sparge Pilot Test Trench
Diamond Head
Focused Phase 2 RI

Project Manager: M. Yocum

Scale : 1' = 0.4"

Drawn by: MY

Date Drawn: April 18, 2008 Revised June 6, 2008 by
 CH2M HILL

Tables

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3-5	Landfill Characterization Sampling Detected Pesticide and PCB Compounds
3-6	Landfill Characterization Sampling Detected Metals
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3-8	Landfill Features of Interest Sampling Detected Semi Organic Compounds
3-9	Landfill Features of Interest Sampling Metals
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8-2	Free Product Sampling IDW Characterization
8-3	Free Product and Decon Water Sampling IDW Characterization Ignitability and Corrosivity
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Table 3-1
Laboratory Tracking Information for Samples Collected During the 2008 Focused Phase 2 RI
Diamond Head
Focused Phase 2 RI

Station ID	Sample ID	Sample Number (for CLP only)	Duplicate Sample Number	Sample Matrix	Sample Type	Composite Yes or No	Sampling Method	Depth of Sample Top	Depth of Sample Bottom	Units	Sample Date	Sample Time	COC Date	Analyses	Case Number	Laboratory
Landfill investigation - Characterization sampling																
LTR-E-01	LTR-E-01-2	LTR-E-01-2/B4TL1/MB4TL1		Soil	SO	N	Hand	6.5	7	ft	2/4/2008	10:30	2/4/2008	TCL-full, TAL-Metals	37193	CLP
LTR-E-02	LTR-E-02-2	LTR-E-02-2/B4TL2/MB4TL2		Soil	SO	N	Hand	3.5	4	ft	2/6/2008	9:09	2/6/2008	TCL-full, TAL-Metals	37193	CLP
LTR-E-03	LTR-E-03-2	LTR-E-03-2/B4TL3/MB4TL3		Soil	SO	N	Hand	7	8	ft	2/6/2008	15:00	2/6/2008	TCL-full, TAL-Metals	37193	CLP
LTR-E-04	LTR-E-04-2	LTR-E-04-2/B4TL4/MB4TL4		Soil	SO	N	Hand	10.5	11	ft	2/11/2008	9:20	2/11/2008	TCL-full, TAL-Metals	37193	CLP
LTR-E-05	LTR-E-05-2	LTR-E-05-2/B4TL5/MB4TL5		Soil	SO	N	Hand	10	10.5	ft	2/11/2008	15:00	2/11/2008	TCL-full, TAL-Metals	37193	CLP
LTR-W-01	LTR-W-01-2	LTR-W-01-2/B4TL6/MB4TL6		Soil	SO	N	Hand	8.5	9	ft	2/12/2008	10:30	2/12/2008	TCL-full, TAL-Metals	37193	CLP
LTR-W-02	LTR-W-02-2	LTR-W-02-2/B4TL7/MB4TL7		Soil	SO	N	Hand	9	9.5	ft	2/13/2008	10:00	2/13/2008	TCL-full, TAL-Metals	37193	CLP
LTR-W-03	LTR-W-03-2	LTR-W-03-2/B4TL8/MB4TL8		Soil	SO	N	Hand	8.5	9	ft	2/14/2008	12:35	2/14/2008	TCL-full, TAL-Metals	37193	CLP
LTR-W-04	LTR-W-04-2	LTR-W-04-2/B4TL0/MB4TL0		Soil	SO	N	Hand	3.5	4	ft	2/15/2008	13:30	2/15/2008	TCL-full, TAL-Metals	37193	CLP
LTR-W-05	LTR-W-05-2	LTR-W-05-2/B4TM3/MB4TM3		Soil	SO	N	Hand	4.5	5	ft	2/18/2008	13:30	2/18/2008	TCL-full, TAL-Metals	37193	CLP
LTR-W-06	LTR-W-06-2	LTR-W-06-2/B4TL9/MB4TL9		Soil	SO	N	Hand	2.5	3	ft	2/14/2008	9:50	2/14/2008	TCL-full, TAL-Metals	37193	CLP
LTR-W-07	LTR-W-07-2	LTR-W-07-2/B4TM1/MB4TM1		Soil	SO	N	Hand	7	7.5	ft	2/15/2008	9:30	2/15/2008	TCL-full, TAL-Metals	37193	CLP
LTR-W-08	LTR-W-08-2	LTR-W-08-2/B4TM2/MB4TM2		Soil	SO	N	Hand	13.5	14	ft	2/15/2008	12:30	2/15/2008	TCL-full, TAL-Metals	37193	CLP
LTR-W-09	LTR-W-09-2	LTR-W-09-2/B4TM4/MB4TM4		Soil	SO	N	Hand	14.5	15	ft	2/18/2008	11:15	2/18/2008	TCL-full, TAL-Metals	37193	CLP
D-2-020608	D-2-020608-01	D-2-020608-01/B4TZ9/MB4TZ9	B4TL3/MB4TL3	Soil	FD	N	Hand	7	8	ft	2/8/2008	15:00	2/8/2008	TCL-full, TAL-Metals	37193	CLP
Landfill investigation - Features of interest sampling																
LTR-F02	LTR-F02-2	NA		Unknown material	SO	N	Hand	NA	NA	NA	4/21/2008	10:40	4/21/2008	TCL-full, TAL-Metals, ignitability, corrosivity	NA	Chemtech
LTR-F07	LTR-F07-2	NA		Unknown material	SO	N	Hand	NA	NA	NA	4/21/2008	10:10	4/21/2008	TCL-full, TAL-Metals	NA	Chemtech
LTR-F13	LTR-F13-2	NA		Unknown material	SO	N	Hand	NA	NA	NA	4/21/2008	10:20	4/21/2008	TCL-full, TAL-Metals	NA	Chemtech
LTR-F14	LTR-F14-2	NA		Unknown material	SO	N	Hand	NA	NA	NA	4/21/2008	10:20	4/21/2008	TCL-full, TAL-Metals	NA	Chemtech
LTR-F15	LTR-F15-2	NA		Unknown material	SO	N	Hand	NA	NA	NA	4/21/2008	10:50	4/21/2008	TCL-full, TAL-Metals, ignitability, corrosivity	NA	Chemtech
Free product investigation - Characterization sampling																
PZ-10	FP-PZ-10-2	NA		Free product	FP	N	Hand	NA	NA	NA	3/26/2008	09:05	3/26/2008	TCL-full, TAL-Metals	NA	Chemtech
Free product investigation - Waste disposal sampling																
Drum 1	FP-IDW-01-2	NA		Free product	IDW	N	Hand	NA	NA	NA	3/26/2008	10:35	3/26/2008	TCLP-full, ignitability, corrosivity	NA	Chemtech
Free product investigation - SPLP testing																
SB-39	SB3905062	NA		Soil	SO	N	Geoprobe	5	6	ft	3/17/2008	13:50	3/17/2008	SPLP VOCs and SVOCs	NA	Chemtech
SB-40	SB3905062	NA		Soil	SO	N	Geoprobe	7	8	ft	3/17/2008	14:45	3/17/2008	SPLP VOCs and SVOCs	NA	Chemtech
SB-41	SB3905062	NA		Soil	SO	N	Geoprobe	15	17	ft	3/17/2008	15:45	3/17/2008	SPLP VOCs and SVOCs	NA	Chemtech
SB-42	SB3905062	NA		Soil	SO	N	Geoprobe	5	6	ft	3/17/2008	16:10	3/17/2008	SPLP VOCs and SVOCs	NA	Chemtech
Airbio sparge pilot testing - Bacterial sampling																
PZ-AS-01	PZ-AS-01-1-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/8/2008	11:50	4/8/2008	Bacteria by PLFA	NA	Microbial Insights
PZ-AS-02	PZ-AS-02-1-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/8/2008	09:45	4/8/2008	Bacteria by PLFA	NA	Microbial Insights
PZ-AS-03	PZ-AS-03-1-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/8/2008	10:40	4/8/2008	Bacteria by PLFA	NA	Microbial Insights
PZ-AS-04	PZ-AS-04-1-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/8/2008	12:50	4/8/2008	Bacteria by PLFA	NA	Microbial Insights
PZ-AS-05	PZ-AS-05-1-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/7/2008	15:15	4/7/2008	Bacteria by PLFA	NA	Microbial Insights
MW-11S	MW-11S-1-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/7/2008	17:15	4/7/2008	Bacteria by PLFA	NA	Microbial Insights
PZ-AS-01	PZ-AS-01-2-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	09:45	4/18/2008	Bacteria by PLFA	NA	Microbial Insights
PZ-AS-02	PZ-AS-02-2-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	10:30	4/18/2008	Bacteria by PLFA	NA	Microbial Insights
PZ-AS-03	PZ-AS-03-2-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	11:15	4/18/2008	Bacteria by PLFA	NA	Microbial Insights
PZ-AS-04	PZ-AS-04-2-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	12:20	4/18/2008	Bacteria by PLFA	NA	Microbial Insights
PZ-AS-05	PZ-AS-05-2-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	13:15	4/18/2008	Bacteria by PLFA	NA	Microbial Insights
MW-11S	MW-11S-1-2	NA		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	13:50	4/18/2008	Bacteria by PLFA	NA	Microbial Insights
Airbio sparge pilot testing - Groundwater sampling																
PZ-AS-01	PZ-AS-01-1-2	B4TM9		Groundwater	GW	N	Pump	NA	NA	NA	4/8/2008	11:50	4/8/2008	TCL-VOCs	37351	CLP
PZ-AS-02	PZ-AS-02-1-2	B4TN0		Groundwater	GW	N	Pump	NA	NA	NA	4/8/2008	09:45	4/8/2008	TCL-VOCs	37351	CLP
PZ-AS-03	PZ-AS-03-1-2	B4TN1		Groundwater	GW	N	Pump	NA	NA	NA	4/8/2008	10:40	4/8/2008	TCL-VOCs	37351	CLP
PZ-AS-04	PZ-AS-04-1-2	B4TN2		Groundwater	GW	N	Pump	NA	NA	NA	4/8/2008	12:50	4/8/2008	TCL-VOCs	37351	CLP
PZ-AS-05	PZ-AS-05-1-2	B4TN2		Groundwater	GW	N	Pump	NA	NA	NA	4/7/2008	15:15	4/7/2008	TCL-VOCs	37351	CLP
MW-11S	MW-11S-1-2	B4TM8		Groundwater	GW	N	Pump	NA	NA	NA	4/7/2008	17:15	4/7/2008	TCL-VOCs	37351	CLP
PZ-AS-01	PZ-AS-01-2-2	B4TN6		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	21:45	4/18/2008	TCL-VOCs	37351	CLP
PZ-AS-02	PZ-AS-02-2-2	B4TN7		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	10:30	4/18/2008	TCL-VOCs	37351	CLP
PZ-AS-03	PZ-AS-03-2-2	B4TN8		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	11:15	4/18/2008	TCL-VOCs	37351	CLP
PZ-AS-04	PZ-AS-04-2-2	B4TN9		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	12:20	4/18/2008	TCL-VOCs	37351	CLP
PZ-AS-05	PZ-AS-05-2-2	B4TP0		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	13:15	4/18/2008	TCL-VOCs	NA	CLP
MW-11S	MW-11S-2-2	B4TN5		Groundwater	GW	N	Pump	NA	NA	NA	4/18/2008	13:50	4/18/2008	TCL-VOCs	37351	CLP
Decon water sampling																
Drum 1	WW-01-2	B4TP2/MB4TP2		Decon water	IDW	N	Hand	NA	NA	NA	4/18/2008	15:30	4/18/2008	TCL-full, TAL-Metals	37351	CLP
Drum 1	WW-01-2	NA		Decon water	IDW	N	Hand	NA	NA	NA	3/26/2008	12:00	3/26/2008	Ignitability and corrosivity	NA	Chemtec
Fire hydrant water sampling																
FH-01	FH-01-2	B4TM5/MB4TM5		Municipal Water Supply	FH	N	Hand	NA	NA	NA	2/19/2008	8:00	2/19/2008	TCL-full, TAL-Metals	37193	
Equipment and trip blanks																
T-2-021908	T-2-021908-01	B4TZ8		Field QC	TB	N	Hand	NA	NA	NA	2/19/2008	14:45	2/19/2008	TCL-VOC	37193	CLP
E-2-021908	E-2-021908-01	B4TM6/MB4TM6		Field QC	EB	N	Hand	NA	NA	NA	2/19/2008	9:00	2/19/2008	TCL-full, TAL-Metals	37193	CLP
E-2-040908	E-2-040908-01	B4TM7		Field QC	EB	N	Hand	NA	NA	NA	4/9/2008	14:15	4/9/2008	TCL-VOC	37351	CLP
T-2-040908	T-2-040908-01	B4TZ7		Field QC	TB	N	Hand	NA	NA	NA	4/9/2008	14:00	4/9/2008	TCL-VOC	37351	CLP
E-2-041808	E-2-041808-01	B4TN4		Field QC	EB	N	Hand	NA	NA	NA	4/18/2008	16:15	4/18/2008	TCL-VOC	37351	CLP
T-2-041808	T-2-041808-01	B4TP1		Field QC	TB	N	Hand	NA	NA	NA	4/18/2008	16:00	4/18/2008	TCL-VOC	37351	CLP

Legend:
SO Soil sample
MS/MSD Matrix spike and duplicate
SL Sludge sample
GW Groundwater sample
SW Surface water
LNAPL Light Non-Aqueous Phase Liquid
TCLP Toxicity Characteristic Leaching Procedure

SD Sediment
FP Free product
FH Fire hydrant
WW Waste water
IDW Investigation Derived Waste

N Normal media sample
FD Field duplicate
EB Equipment blank
TB Trip blank
MSD Matrix Spike/ Matrix Spike Duplicate

TCL-fill
TCL SVOC
TAL Total Metals
VOC
SVOC

Target compound list - volatile organic compounds, semi-volatile organic compounds, PCBs, pesticides
Target compound list - semi volatile organic compounds
Target analyte list for total metals
Volatile Organic Compound
Semi-Volatile Organic Compound

Table 3-2
Summary of Features of Interest Identified During the Landfill Investigation
Diamond Head
Focused Phase 2 RI

Feature Identification	Feature GPS		Landfill Trench Segment	PID Reading (ppm)	Feature Description	Feature Overpacked (Y/N)?	Material Sampled
	Northing	Easting					
Feature 1	697911.133	593751.637	LTR-E-10	0	Crushed 30-gallon poly drum. No contents, no odor.	N	N
Feature 2	697885.106	593753.386	LTR-E-11	0	Crushed cardboard drum containing gelatin like substance. Removed, overpacked, and later sampled. No odor. Feature sample LTR-F02-2	Y	Y
Feature 3	697783.017	593774.187	LTR-E-16	25	Crushed steel drum. Soil inside drum shell had PID reading of 25 ppm. Soil around drum had PID reading of 18 ppm. No evidence of original contents.	N	N
Feature 4	697775.281	593776.379	LTR-E-16	0	Crushed steel drum with no contents. No PID reading or odor around drum.	N	N
Feature 5	697756.148	593780.352	LTR-E-17	200	Crushed steel drum containing soil and intermixed plastic sheets. PID reading of soil inside drum was 200 ppm. Drum left in landfill.	N	N
Feature 6	697654.286	593774.421	LTR-E-21	0	Crushed steel drum. No contents inside drum, no PID reading inside drum.	N	N
Feature 7	697635.025	593780.329	LTR-E-22	0	A yellowish resin-like material present in large chunks (approximately 3 ft by 1.5 ft). Material was intermixed with soil and refuse. Very strong pungent odor present in material/soil. Material sampled. Feature sample LTR-F07-2	N	Y
Feature 8	697597.078	593808.518	LTR-E-24	0	Narrow, 4 ft long metal tank with fittings on top of tank discovered 1 to 2 ft below ground surface. Object appears to be a water heating tank. No contents, no PID reading.	N	N
Feature 9	697395.182	593852.628	LTR-E-32	0	Crushed steel drum uncovered at 9 ft below ground surface. No contents, no odors, no PID reading.	N	N
Feature 10	697373.563	593856.941	LTR-E-33	0	Crushed steel drum uncovered at 6 ft below ground surface. No contents, no odors, no PID reading.	N	N
Feature 11	697964.612	593664.578	LTR-W-05	177	Crushed steel drum with rags and a black gray unknown substance intermixed with sand and clay-like material. PID reading peaked at 177 ppm over substance.	N	N
Feature 12	697911.257	593666.784	LTR-W-07	0	Crushed steel drum containing rags, spackle knives, and a gray ash (possibly concrete powder). No PID reading or odors. Encountered second crushed drum which appeared to contain soil with rust staining. No PID reading or odors.	N	N

Table 3-2
Summary of Features of Interest Identified During the Landfill Investigation
Diamond Head
Focused Phase 2 RI

Feature Identification	Feature GPS		Landfill Trench Segment	PID Reading (ppm)	Feature Description	Feature Overpacked (Y/N)?	Material Sampled
	Northing	Easting					
Feature 13	697890.081	593669.317	LTR-W-08	2	Clear to white sticky resin / glue-like material present throughout spoils. Material sampled. Feature sample LTR-F13-2	N	Y
Feature 14	697846.289	593668.997	LTR-W-10	0	Unknown black, sticky, hard resin-like material located at 3 ft below ground surface throughout entire trench segment. Material sampled. Feature sample LTR-F14-2	N	Y
Feature 15	697793.546	593671.116	LTR-W-12	1,352	Feature 15 - Crushed steel drum encountered at 3 ft below ground surface. Very strong ether-like odor. Drum contained a purplish, hard foam material with some pinkish resin like material (approximately 12oz). PID reading at 1352 ppm. Material overpacked and sampled. Feature sample LTR-F15-2	Y	Y
Feature 16	697770.492	593670.353	LTR-W-13	0	Crushed steel container (approximately 200 gallons) encountered. No PID reading, no odor. Drum appeared to contain soil similar to landfill fill-material.	N	N
Feature 17	697719.51	593668.672	LTR-W-15	0	Crushed steel drum encountered at 2 ft below ground surface containing ash-like material and soil. No odor or PID reading or evidence of original content.	N	N
Feature 18	697688.227	593664.425	LTR-W-16	45	Partially intact steel drum w/ white clay like material inside (putty like). PID reading at 45 ppm. No odor.	N	N
Feature 19	697628.809	593665.565	LTR-W-18	5	Crushed shell of a steel drum encountered at 4 ft below ground surface. Drum contained small amount of wet sandy soil/sludge with slight petroleum-like odor. PID reading at 5 ppm.	N	N
Feature 20	697549.312	593663.297	LTR-W-21	0	Crushed steel drum with no odor, no PID reading, and no contents.	N	N
Feature 22	697265.622	593671.465	LTR-W-32	0	Crushed drum which leaked a white clay like substance over spoil pile (lost contents while extraction). No PID reading, strong odor, contained fabric.	N	N

**Table 3-3
Landfill Characterization Sampling
Detected Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI**

Station ID	(A)	(B)	LTR-E-01	LTR-E-02	LTR-E-03	LTR-E-03	LTR-E-04
Sample ID	2008 NJ	2008 NJ	LTR-E-01-2RE	LTR-E-02-2	D-2-020608-01RE	LTR-E-03-2RE	LTR-E-04-2RE
Sample Date	Nonresidential	Residential Soil	02/04/2008	02/06/2008	02/06/2008	02/06/2008	02/11/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	6.5 - 7 ft	3.5 - 4 ft	7 - 8 ft	7 - 8 ft	10.5 - 11 ft
Chemical Name	Criteria						
Volatile Organic Compounds (ug/kg)							
Acetone		70000000	310		150	140	83
Benzene	5000	2000	23 J		23 J	22 J	
Carbon disulfide	110000000	7800000	13 J		5 J	5.1 J	
Chlorobenzene	7400000	510000	130 J		29 J	37 J	32
Cyclohexane							
Dichlorobenzene-1,2	59000000	5300000	100 J		26 J	32 J	
Dichlorobenzene-1,4	13000	5000	280 J		75 J	91 J	
Dichlorodifluoromethane	230000000	490000					
Dichloroethane-1,1	24000	8000					
Dichloropropene-1,3 cis							
Ethylbenzene	110000000	7800000	11 J	800	14 J	31 J	
Isopropylbenzene			100 J	1700	43 J	52 J	39 J
Methyl cyclohexane			30 J	640	23 J	20 J	6.1 J
Methyl ethyl ketone (2-butanone)	44000000	3100000	86		36	34	
Methyl isobutyl ketone (4-methyl-2-pentanone)							
Styrene	260000	90000					
Tetrachloroethane-1,1,2,2	3000	1000				8.9 J	
Tetrachloroethylene	5000	2000					
Toluene	91000000	6300000	6.3 J	290 J	7.4 J	5.3 J	
Trichloroethane-1,1,1	4200000	290000					
Trichloroethylene	20000	7000					
Xylene-m & p - (Sum of Isomers)	12000000	170000000	14 J	990	89 J	84 J	
Xylene-o	12000000	170000000	23 J	830	27 J	31 J	

6/5/2008

**Table 3-3
Landfill Characterization Sampling
Detected Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI**

Station ID	(A) 2008 NJ Nonresidential Soil Cleanup Criteria	(B) 2008 NJ Residential Soil Cleanup Criteria	LTR-E-05	LTR-W-01	LTR-W-02	LTR-W-03	LTR-W-04
Sample ID			LTR-E-05-2	LTR-W-01-2	LTR-W-02-2	LTR-W-03-2	LTR-W-04-2
Sample Date			02/11/2008	02/12/2008	02/13/2008	02/14/2008	02/15/2008
Sample Interval			10 - 10.5 ft	8.5 - 9 ft	9 - 9.5 ft	8.5 - 9 ft	3.5 - 4 ft
Chemical Name							
Volatile Organic Compounds (ug/kg)							
Acetone		70000000	63	140	260	280	440
Benzene	5000	2000	9.2 J	31 J	38 J	24 J	10 J
Carbon disulfide	110000000	7800000		3.3 J	7.5 J	20 J	
Chlorobenzene	7400000	510000	18 J	24	240	52	430 J
Cyclohexane				13 J	7.7 J	6.3 J	
Dichlorobenzene-1,2	59000000	5300000	9 J			19 J	
Dichlorobenzene-1,4	13000	5000			150 J	58 J	250 J
Dichlorodifluoromethane	230000000	490000					450 J
Dichloroethane-1,1	24000	8000					
Dichloropropene-1,3 cis							
Ethylbenzene	110000000	7800000		86 J	640	7.3 J	
Isopropylbenzene			25 J	190 J	240 J	130 J	110 J
Methyl cyclohexane			12 J	47 J	19 J		
Methyl ethyl ketone (2-butanone)	44000000	3100000		46	68	82	140
Methyl isobutyl ketone (4-methyl-2-pentanone)							
Styrene	260000	90000		12 J			
Tetrachloroethane-1,1,2,2	3000	1000					
Tetrachloroethylene	5000	2000					
Toluene	91000000	6300000		17 J	17 J	6.4 J	6.9 J
Trichloroethane-1,1,1	4200000	290000					
Trichloroethylene	20000	7000					
Xylene-m & p - (Sum of Isomers)	12000000	170000000	5.9 J	80 J	170 J	37 J	14 J
Xylene-o	12000000	170000000	9 J	260 J	560 J	65 J	7.7 J

6/5/2008

**Table 3-3
Landfill Characterization Sampling
Detected Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI**

Station ID	(A)	(B)	LTR-W-05	LTR-W-06	LTR-W-07	LTR-W-08	LTR-W-09
Sample ID	2008 NJ	2008 NJ	LTR-W-05-2	LTR-W-06-2	LTR-W-07-2	LTR-W-08-2	LTR-W-09-2
Sample Date	Nonresidential	Residential Soil	02/18/2008	02/14/2008	02/15/2008	02/15/2008	02/18/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	4.5 - 5 ft	2.5 - 3 ft	7 - 7.5 ft	13.5 - 14 ft	14.5 - 15 ft
Chemical Name	Criteria						
Volatile Organic Compounds (ug/kg)							
Acetone		70000000	140				240
Benzene	5000	2000	51 J	8.7 J			6800 (AB)
Carbon disulfide	110000000	7800000	7.3 J				7.9 J
Chlorobenzene	7400000	510000	100			16000	34000
Cyclohexane				14 J			31 J
Dichlorobenzene-1,2	59000000	5300000	15 J				640 J
Dichlorobenzene-1,4	13000	5000	62 J				1300
Dichlorodifluoromethane	230000000	490000					
Dichloroethane-1,1	24000	8000		24			
Dichloropropene-1,3 cis						390 J	
Ethylbenzene	110000000	7800000			15000		440 J
Isopropylbenzene			41 J		3600	8400	400 J
Methyl cyclohexane				20 J		1100	54 J
Methyl ethyl ketone (2-butanone)	44000000	3100000	57				92
Methyl isobutyl ketone (4-methyl-2-pentanone)					6400		
Styrene	260000	90000					
Tetrachloroethane-1,1,2,2	3000	1000					
Tetrachloroethylene	5000	2000					14 J
Toluene	91000000	6300000	4.3 J	1000	43000		31 J
Trichloroethane-1,1,1	4200000	290000		24			
Trichloroethylene	20000	7000					39 J
Xylene-m & p - (Sum of Isomers)	12000000	170000000	6 J	7.4 J	43000		170 J
Xylene-o	12000000	170000000		3.4 J	15000		70 J

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Table 3-4
Landfill Characterization Sampling
Detected Semi Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Station ID	(A)	(B)	LTR-E-01	LTR-E-02	LTR-E-03	LTR-E-03	LTR-E-04
Sample ID	2008 NJ	2008 NJ	LTR-E-01-2	LTR-E-02-2	D-2-020608-01	LTR-E-03-2	LTR-E-04-2
Sample Date	Nonresidential	Residential Soil	02/04/2008	02/06/2008	02/06/2008	02/06/2008	02/11/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	6.5 - 7 ft	3.5 - 4 ft	7 - 8 ft	7 - 8 ft	10.5 - 11 ft
Chemical Name							
Semivolatile Organic Compounds (ug/kg)							
Acenaphthene	37000000	3400000	780	6800	960	1000	400
Acenaphthylene	300000000		380	2300 J	710	620	180 J
Acetophenone	5000	2000					
Anthracene	30000000	17000000	770	5700	1600	1400	510
Benzaldehyde	68000000	6100000	440				
Benzo(a)anthracene	2000	600	1300 (B)	4900 (AB)	2600 (AB)	2300 (AB)	1600 (B)
Benzo(a)pyrene	200	200	1300 J (AB)	4300 (AB)	2800 (AB)	2400 J (AB)	1300 (AB)
Benzo(b)fluoranthene	2000	600	1500 J (B)	3800 (AB)	3200 (AB)	2800 J (AB)	1600 (B)
Benzo(g,h,i)perylene	30000000	380000000	770 J	2500 J	1200	1200 J	400
Benzo(k)fluoranthene	23000	6000	740 J	1800 J	1500	1200 J	890
Biphenyl	34000000	3100000	160 J	940 J	170 J	200 J	430
Butylbenzyl phthalate	14000000	1200000	65000	9200			
Caprolactam	340000000	31000000					
Carbazole	96000	24000	130 J		480	370	180 J
Chloronaphthalene-2							
Chrysene	230000	62000	1400	4500	2900	2800	1500
Cresol-o	3400000	310000					
Cresol-p	340000	31000			130 J		
Dibenzo(a,h)anthracene	200	200	270 J (AB)	720 J (AB)	480 (AB)	490 J (AB)	160 J
Dibenzofuran			320 J		500	310	180 J
Dimethylphenol-2,4	14000000	1200000					
Fluoranthene	24000000	2300000	3000	9700	4900	4900	2700
Fluorene	24000000	2300000	720	7300	950	820	390
Hexachlorobenzene	1000	300			2900 (AB)	1800 (AB)	
Indeno(1,2,3-cd)pyrene	2000	600	650 J (B)	1800 J (B)	1300 (B)	1300 J (B)	500
Methylnaphthalene-2	2400000	230000	940	140000	710	820	110 J
Naphthalene	17000	6000	24000 (AB)	340000 (AB)	1300	1400	100 J
Nitrosodiphenylamine-n	390000	99000					
Phenanthrene	300000000		2500	19000	5000	4100	1500
Phenol	210000000	18000000					
Phthalate, bis(2-ethylhexyl) (DEHP)	140000	35000	38000 (B)	170000 (AB)	6500	7100	4300

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Table 3-4
Landfill Characterization Sampling
Detected Semi Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Station ID	(A)	(B)	LTR-E-01	LTR-E-02	LTR-E-03	LTR-E-03	LTR-E-04
Sample ID	2008 NJ	2008 NJ	LTR-E-01-2	LTR-E-02-2	D-2-020608-01	LTR-E-03-2	LTR-E-04-2
Sample Date	Nonresidential	Residential Soil	02/04/2008	02/06/2008	02/06/2008	02/06/2008	02/11/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	6.5 - 7 ft	3.5 - 4 ft	7 - 8 ft	7 - 8 ft	10.5 - 11 ft
Chemical Name	Criteria						
Semivolatile Organic Compounds (ug/kg)							
Phthalate, diethyl	550000000	49000000					
Phthalate, di-n-butyl	68000000	6100000	140 J		110 J		190 J
Phthalate, di-n-octyl	27000000	2400000		4500		110 J	
Pyrene	18000000	1700000	2900	12000	7800	6700	2800

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Table 3-4
Landfill Characterization Sampling
Detected Semi Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Station ID	(A)	(B)	LTR-E-05	LTR-W-01	LTR-W-02	LTR-W-03	LTR-W-04
Sample ID	2008 NJ	2008 NJ	LTR-E-05-2	LTR-W-01-2	LTR-W-02-2	LTR-W-03-2	LTR-W-04-2
Sample Date	Nonresidential	Residential Soil	02/11/2008	02/12/2008	02/13/2008	02/14/2008	02/15/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	10 - 10.5 ft	8.5 - 9 ft	9 - 9.5 ft	8.5 - 9 ft	3.5 - 4 ft
Chemical Name	Criteria						
Semivolatile Organic Compounds (ug/kg)							
Acenaphthene	37000000	3400000	11000	32000	7200	2300	2200
Acenaphthylene	300000000		2800	4500 J	1700	780	980
Acetophenone	5000	2000					
Anthracene	30000000	17000000	6300	29000	5700	2200	1800
Benzaldehyde	68000000	6100000		280 J	140 J	120 J	
Benzo(a)anthracene	2000	600	11000 (AB)	24000 (AB)	5600 (AB)	2800 (AB)	3200 (AB)
Benzo(a)pyrene	200	200	8800 (AB)	20000 (AB)	5400 (AB)	2500 (AB)	2700 (AB)
Benzo(b)fluoranthene	2000	600	7400 (AB)	16000 (AB)	4700 (AB)	2400 (AB)	2800 (AB)
Benzo(g,h,i)perylene	30000000	380000000	4300	5800 J	2000	990	560
Benzo(k)fluoranthene	23000	6000	3700	6800 J (B)	2400	860	1700
Biphenyl	34000000	3100000	110 J	330 J	120 J	73 J	55 J
Butylbenzyl phthalate	14000000	1200000					180 J
Caprolactam	340000000	31000000					980
Carbazole	96000	24000	280	480 J	220 J	95 J	
Chloronaphthalene-2							
Chrysene	230000	62000	9000	7100 J	5900	2600	3300
Cresol-o	3400000	310000					
Cresol-p	340000	31000	77 J	140 J	58 J	42 J	
Dibenzo(a,h)anthracene	200	200	1800 (AB)	2600 J (AB)	840 (AB)	390 (AB)	520 (AB)
Dibenzofuran			690	1800 J	520 J	190 J	350
Dimethylphenol-2,4	14000000	1200000					
Fluoranthene	24000000	2300000	14000	39000	8200	3700	5000
Fluorene	24000000	2300000	3500	24000	5100	1600	1600
Hexachlorobenzene	1000	300					
Indeno(1,2,3-cd)pyrene	2000	600	3300 (AB)	5800 J (AB)	2100 (AB)	950 (B)	1300 (B)
Methylnaphthalene-2	2400000	230000	450	7200 J	7400	2300	1200
Naphthalene	17000	6000	740	6000 J (B)	7100 (B)	2600	330
Nitrosodiphenylamine-n	390000	99000					
Phenanthrene	300000000		16000	66000	20000	4300	4600
Phenol	210000000	18000000					
Phthalate, bis(2-ethylhexyl) (DEHP)	140000	35000	390	330 J	2300	1100	10000

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**Table 3-4
Landfill Characterization Sampling
Detected Semi Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI**

Station ID	(A) 2008 NJ Nonresidential Soil Cleanup Criteria	(B) 2008 NJ Residential Soil Cleanup Criteria	LTR-E-05	LTR-W-01	LTR-W-02	LTR-W-03	LTR-W-04
Sample ID			LTR-E-05-2	LTR-W-01-2	LTR-W-02-2	LTR-W-03-2	LTR-W-04-2
Sample Date			02/11/2008	02/12/2008	02/13/2008	02/14/2008	02/15/2008
Sample Interval			10 - 10.5 ft	8.5 - 9 ft	9 - 9.5 ft	8.5 - 9 ft	3.5 - 4 ft
Chemical Name							
Semivolatile Organic Compounds (ug/kg)							
Phthalate, diethyl	550000000	49000000					
Phthalate, di-n-butyl	68000000	6100000				28 J	97 J
Phthalate, di-n-octyl	27000000	2400000			110 J		170 J
Pyrene	18000000	1700000	27000	48000	7600	3700	5600

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Table 3-4
Landfill Characterization Sampling
Detected Semi Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Station ID	(A)	(B)	LTR-W-05	LTR-W-06	LTR-W-07	LTR-W-08	LTR-W-09
Sample ID	2008 NJ	2008 NJ	LTR-W-05-2	LTR-W-06-2	LTR-W-07-2	LTR-W-08-2	LTR-W-09-2
Sample Date	Nonresidential	Residential Soil	02/18/2008	02/14/2008	02/15/2008	02/15/2008	02/18/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	4.5 - 5 ft	2.5 - 3 ft	7 - 7.5 ft	13.5 - 14 ft	14.5 - 15 ft
Chemical Name	Criteria						
Semivolatile Organic Compounds (ug/kg)							
Acenaphthene	37000000	3400000	1400	280	3100	1500	910
Acenaphthylene	300000000		550	550	1000	880	1000
Acetophenone	5000	2000		84 J	7700 (AB)		
Anthracene	30000000	17000000	1200	540	2100	2200	1500
Benzaldehyde	68000000	6100000		110 J			
Benzo(a)anthracene	2000	600	1700 J (B)	990 (B)	2600 J (AB)	3400 (AB)	2700 (AB)
Benzo(a)pyrene	200	200	1600 (AB)	1000 (AB)	2600 (AB)	2700 (AB)	2500 (AB)
Benzo(b)fluoranthene	2000	600	1800 (B)	1200 (B)	2700 (AB)	2800 (AB)	2700 (AB)
Benzo(g,h,i)perylene	30000000	380000000	250	730	990	780	1100
Benzo(k)fluoranthene	23000	6000	710	520	1300	1700	1600
Biphenyl	34000000	3100000	41 J	64 J	200 J	86 J	130 J
Butylbenzyl phthalate	14000000	1200000	71 J		160 J		
Caprolactam	340000000	31000000	190 J		380	3300	310
Carbazole	96000	24000	100 J	47 J	160 J	230 J	160 J
Chloronaphthalene-2						390	
Chrysene	230000	62000	1800 J	1100	2800 J	3100	2900
Cresol-o	3400000	310000		890			
Cresol-p	340000	31000		130 J	110 J		61 J
Dibenzo(a,h)anthracene	200	200	280 (AB)	260 J (AB)	450 (AB)	470 (AB)	480 (AB)
Dibenzofuran			130 J	57 J	330	450	190 J
Dimethylphenol-2,4	14000000	1200000					67 J
Fluoranthene	24000000	2300000	2700 J	1500	4300	3500	4700
Fluorene	24000000	2300000	1000	230 J	2200	1700	880
Hexachlorobenzene	1000	300					
Indeno(1,2,3-cd)pyrene	2000	600	740 (B)	710 (B)	1200 (B)	1300 (B)	1300 (B)
Methylnaphthalene-2	2400000	230000	230 J	200 J	2400	2300	460
Naphthalene	17000	6000	610	580	1600	1700	640
Nitrosodiphenylamine-n	390000	99000	170 J				310
Phenanthrene	300000000		2700	1000	6200	4000	2900
Phenol	210000000	18000000		40 J			74 J
Phthalate, bis(2-ethylhexyl) (DEHP)	140000	35000		650	4500 J	20000	5400

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Table 3-4
Landfill Characterization Sampling
Detected Semi Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Station ID	(A)	(B)	LTR-W-05	LTR-W-06	LTR-W-07	LTR-W-08	LTR-W-09
Sample ID	2008 NJ Nonresidential Soil Cleanup Criteria	2008 NJ Residential Soil Cleanup Criteria	LTR-W-05-2	LTR-W-06-2	LTR-W-07-2	LTR-W-08-2	LTR-W-09-2
Sample Date			02/18/2008	02/14/2008	02/15/2008	02/15/2008	02/18/2008
Sample Interval			4.5 - 5 ft	2.5 - 3 ft	7 - 7.5 ft	13.5 - 14 ft	14.5 - 15 ft
Chemical Name							
Semivolatile Organic Compounds (ug/kg)							
Phthalate, diethyl	550000000	490000000			270 J		
Phthalate, di-n-butyl	680000000	61000000	25 J	53 J	110 J	410	71 J
Phthalate, di-n-octyl	270000000	24000000			260 J	420	100 J
Pyrene	180000000	17000000	2500 J	1400	3300 J	5100	3800

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**Table 3-5
Landfill Characterization Sampling
Detected Pesticide and PCB Compounds
Diamond Head
Focused Phase 2 RI**

Station ID	(A)	(B)	LTR-E-01	LTR-E-02	LTR-E-03	LTR-E-03	LTR-E-04
Sample ID	2008 NJ	2008 NJ	LTR-E-01-2	LTR-E-02-2	D-2-020608-01	LTR-E-03-2	LTR-E-04-2
Sample Date	Nonresidential	Residential Soil	02/04/2008	02/06/2008	02/06/2008	02/06/2008	02/11/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	6.5 - 7 ft	3.5 - 4 ft	7 - 8 ft	7 - 8 ft	10.5 - 11 ft
Chemical Name	Criteria						
Pesticides and PCBs (ug/kg)							
Aldrin	200	40		18 J			
BHC, alpha	500	100		20 J	14 J	8.4 J	6.7 J
BHC, beta	2000	400			19 J		6.5 J
BHC, delta			150	18 J	96 J	140 J	
BHC, gamma (Lindane)	2000	400	19 J		20 J		
Chlordane - alpha							
Chlordane - beta					21 J		
DDD-4,4	13000	3000	38 J	53 J	83 J	130 J	21 J
DDE-4,4	9000	2000	33 NJ	53 NJ	46 NJ	27 JN	13 NJ
DDT-4,4	8000	2000	100 J	240 J	52	340 J	16 J
Dieldrin	200	40			9.5 J	17 J	
Endosulfan I (alpha)							
Endosulfan Sulfate	6800000	470000					
Endrin	340000	23000				5 J	2.8 J
Endrin Aldehyde					3.9 J		
Endrin ketone			7.3 J			12 J	18 J
Heptachlor	700	100			15 J	14 J	2.3 J
Heptachlor Epoxide	300	70	140 (B)	53 J	80 J (B)	100 J (B)	
Methoxychlor	5700000	390000		120 J	19 J		21 J
Aroclors (ug/kg)							
Pcb-araclor 1242	200	1000	1900 J (AB)	830 JN (A)	1900 J (AB)	2500 JN (AB)	110 JN
Pcb-araclor 1248	200	1000					
Pcb-araclor 1254	200	1000	1300 (AB)	1000 (AB)	2300 (AB)	2300 J (AB)	220 JN (A)
Pcb-araclor 1260	200	1000					

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**Table 3-5
Landfill Characterization Sampling
Detected Pesticide and PCB Compounds
Diamond Head
Focused Phase 2 RI**

Station ID	(A)	(B)	LTR-E-05	LTR-W-01	LTR-W-02	LTR-W-03	LTR-W-04
Sample ID	2008 NJ	2008 NJ	LTR-E-05-2	LTR-W-01-2	LTR-W-02-2	LTR-W-03-2	LTR-W-04-2
Sample Date	Nonresidential	Residential Soil	02/11/2008	02/12/2008	02/13/2008	02/14/2008	02/15/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	10 - 10.5 ft	8.5 - 9 ft	9 - 9.5 ft	8.5 - 9 ft	3.5 - 4 ft
Chemical Name	Criteria						
Pesticides and PCBs (ug/kg)							
Aldrin	200	40			15 J		
BHC, alpha	500	100		12 J	2 J	3.9 J	3.2 J
BHC, beta	2000	400		32 J	11 J	6.4 J	
BHC, delta			1100	24 J	45 J	5.3 J	99 J
BHC, gamma (Lindane)	2000	400					
Chlordane - alpha			32 J	26 J		15 J	
Chlordane - beta							19 J
DDD-4,4	13000	3000		63 J	60 J	45 J	21 J
DDE-4,4	9000	2000	42 JN	32 NJ		5.3 JN	9.9 JN
DDT-4,4	8000	2000		20 J	30 J		27 J
Dieldrin	200	40					
Endosulfan I (alpha)			14 J				
Endosulfan Sulfate	6800000	470000	65 J	68 J	39 J		
Endrin	340000	23000		6.5 J	3 J		
Endrin Aldehyde				13 J	10 J		
Endrin ketone			17 J	13 J		6.4 J	
Heptachlor	700	100	110 J (B)	14 J	12 J		19 J
Heptachlor Epoxide	300	70	280 J (B)			7.7 J	87 (B)
Methoxychlor	5700000	390000		42 J	55 J		
Aroclors (ug/kg)							
Pcb-araclor 1242	200	1000	8100 JN (AB)	230 J (A)	880 J (A)	130 J	
Pcb-araclor 1248	200	1000					3000 (AB)
Pcb-araclor 1254	200	1000		200 J (A)	520 J (A)	46 J	
Pcb-araclor 1260	200	1000					

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**Table 3-5
Landfill Characterization Sampling
Detected Pesticide and PCB Compounds
Diamond Head
Focused Phase 2 RI**

Station ID	(A)	(B)	LTR-W-05	LTR-W-06	LTR-W-07	LTR-W-08	LTR-W-09
Sample ID	2008 NJ	2008 NJ	LTR-W-05-2	LTR-W-06-2	LTR-W-07-2	LTR-W-08-2	LTR-W-09-2
Sample Date	Nonresidential	Residential Soil	02/18/2008	02/14/2008	02/15/2008	02/15/2008	02/18/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	4.5 - 5 ft	2.5 - 3 ft	7 - 7.5 ft	13.5 - 14 ft	14.5 - 15 ft
Chemical Name	Criteria						
Pesticides and PCBs (ug/kg)							
Aldrin	200	40				22 J	
BHC, alpha	500	100	1200 (AB)		54 J	43 J	180000 (AB)
BHC, beta	2000	400	130		44 J		59000 (AB)
BHC, delta			62	2.6 J	61 J	47 J	
BHC, gamma (Lindane)	2000	400	28	3.8 J	14 J		
Chlordane - alpha						13 J	
Chlordane - beta							
DDD-4,4	13000	3000	53 J	5 J	47 J	240	
DDE-4,4	9000	2000	49 JN			52 JN	
DDT-4,4	8000	2000	30 J	35 J	68 J	62 J	
Dieldrin	200	40			16 J	17 J	
Endosulfan I (alpha)							
Endosulfan Sulfate	6800000	470000					
Endrin	340000	23000			3.6 J		
Endrin Aldehyde					7.7 J	14 J	
Endrin ketone					18 J	12 J	
Heptachlor	700	100			16 J		
Heptachlor Epoxide	300	70			36 J		
Methoxychlor	5700000	390000					
Aroclors (ug/kg)							
Pcb-aracior 1242	200	1000		250 J (A)			
Pcb-aracior 1248	200	1000	880 (A)		2300 (AB)	2700 (AB)	4900 J (AB)
Pcb-aracior 1254	200	1000		770 (A)			
Pcb-aracior 1260	200	1000			1700 (AB)	2300 (AB)	

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**Table 3-6
Landfill Characterization Sampling
Detected Metals
Diamond Head
Focused Phase 2 RI**

Station ID	(A)	(B)	LTR-E-01	LTR-E-02	LTR-E-03	LTR-E-03	LTR-E-04
Sample ID	2008 NJ	2008 NJ	LTR-E-01-2	LTR-E-02-2	D-2-020608-01	LTR-E-03-2	LTR-E-04-2
Sample Date	Nonresidential	Residential Soil	02/04/2008	02/06/2008	02/06/2008	02/06/2008	02/11/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	6.5 - 7 ft	3.5 - 4 ft	7 - 8 ft	7 - 8 ft	10.5 - 11 ft
Chemical Name	Criteria						
Metals (ug/kg)							
Aluminum		78000000	16100000	6270000	4330000 J	11200000 J	8930000
Antimony	450000	31000	16200	22500	9500 J	12300	3000 J
Arsenic	19000	19000	19600 (AB)	23200 (AB)	12300 J	22900 J (AB)	10300
Barium	59000000	16000000	689000	428000	432000	931000	369000
Beryllium	140000	16000	360 J	370 J		390 J	1400
Cadmium	78000	78000	10400 J	11700 J	9900 J	12900 J	3300 J
Calcium			20700000 J	8240000 J	13100000 J	23100000 J	29000000 J
Chromium			121000	117000	73500 J	143000 J	66700
Cobalt	590000	1600000	15900	11800	8100 J	13100	15500
Copper	45000000	3100000	444000	231000	353000 J	553000 J	350000
Iron			76800000 J	21800000 J	57100000 J	35100000 J	43100000 J
Lead	800000	400000	1040000 J (AB)	673000 J (B)	726000 J (B)	1390000 J (AB)	614000 J (B)
Magnesium			2880000	2330000	1880000	2900000	5210000
Manganese	5900000	11000000	558000	219000	367000	310000	546000
Mercury	65000	23000	10800	6800	4100	3800	1800
Nickel	23000000	1600000	223000	54600			75400
Potassium			1070000 J	886000 J	663000 J	1160000 J	1150000 J
Selenium	5700000	390000	9700	4500 J	7200	5900	5300 J
Silver	5700000	390000	4900	3600	4000 J	7300 J	4400
Sodium			818000 J	663000 J	564000 J	841000	1100000
Thallium	79000	5000			2100 J		
Vanadium	11000000	78000	74500	37000	27600	42300	35700
Zinc	110000000	23000000	1720000	1310000	819000 J	1470000 J	462000

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**Table 3-6
Landfill Characterization Sampling
Detected Metals
Diamond Head
Focused Phase 2 RI**

Station ID	(A)	(B)	LTR-E-05	LTR-W-01	LTR-W-02	LTR-W-03	LTR-W-04
Sample ID	2008 NJ	2008 NJ	LTR-E-05-2	LTR-W-01-2	LTR-W-02-2	LTR-W-03-2	LTR-W-04-2
Sample Date	Nonresidential	Residential Soil	02/11/2008	02/12/2008	02/13/2008	02/14/2008	02/15/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	10 - 10.5 ft	8.5 - 9 ft	9 - 9.5 ft	8.5 - 9 ft	3.5 - 4 ft
Chemical Name	Criteria						
Metals (ug/kg)							
Aluminum		78000000	6900000	4270000	6240000	2060000	3750000
Antimony	450000	31000	9100	5000 J	4600 J	2300 J	4900 J
Arsenic	19000	19000	34500 (AB)	23100 (AB)	20200 (AB)	2700	11800
Barium	59000000	16000000	278000	251000	183000	38300	154000
Beryllium	140000	16000					
Cadmium	78000	78000	1600 J	1800	2100	430 J	1300
Calcium			4410000 J	9570000	2820000	1330000	4490000
Chromium			189000	127000	87800	16200	58000
Cobalt	590000	1600000	8500	5600 J	7800 J	1400 J	3800 J
Copper	45000000	3100000	475000	222000	176000	30100	135000
Iron			17400000 J	12900000	16000000	4460000	17300000
Lead	800000	400000	438000 J (B)	447000 (B)	300000	77800	471000 (B)
Magnesium			3070000	5510000	1960000	988000	1010000
Manganese	5900000	11000000	298000	126000	111000	27300	140000
Mercury	65000	23000	5400	2900	5700	3400	3600
Nickel	23000000	1600000	66500	40800	42600	6300 J	31900
Potassium			899000 J	695000 J	589000 J	381000 J	284000 J
Selenium	5700000	390000	2900 J				
Silver	5700000	390000	2600	2300	2300	250 J	1600
Sodium				654000 J	468000 J	659000 J	298000 J
Thallium	79000	5000					
Vanadium	1100000	78000	29400	26400	21200	6800 J	13300
Zinc	110000000	23000000	698000	487000	477000	162000	425000

5/16/2008

Table 3-6
Landfill Characterization Sampling
Detected Metals
Diamond Head
Focused Phase 2 RI

Station ID	(A)	(B)	LTR-W-05	LTR-W-06	LTR-W-07	LTR-W-08	LTR-W-09
Sample ID	2008 NJ	2008 NJ	LTR-W-05-2	LTR-W-06-2	LTR-W-07-2	LTR-W-08-2	LTR-W-09-2
Sample Date	Nonresidential	Residential Soil	02/18/2008	02/14/2008	02/15/2008	02/15/2008	02/18/2008
Sample Interval	Soil Cleanup	Cleanup Criteria	4.5 - 5 ft	2.5 - 3 ft	7 - 7.5 ft	13.5 - 14 ft	14.5 - 15 ft
Chemical Name							
Metals (ug/kg)							
Aluminum		78000000	5260000	3670000	4720000	2340000 J	6430000
Antimony	450000	31000	5700 J	2800 J	5400 J	5700 J	9300
Arsenic	19000	19000	17500	7700	14700	17100 J	28700 (AB)
Barium	59000000	16000000	216000	142000	270000	264000 J	579000
Beryllium	140000	16000					
Cadmium	78000	78000	3400	1300	4200	1700 J	4300
Calcium			3940000	2000000	10300000	6520000 J	6690000
Chromium			93200	48100	88600	40600 J	142000
Cobalt	590000	1600000	7500 J	5000 J	6000 J	9000 J	9600
Copper	45000000	3100000	221000	110000	210000	402000 J	317000
Iron			26100000	10900000	23800000	40400000 J	29000000
Lead	800000	400000	391000	213000	590000 (B)	623000 J (B)	765000 (B)
Magnesium			1610000	993000	1690000	985000 J	2310000
Manganese	5900000	11000000	184000	110000	206000	216000 J	280000
Mercury	65000	23000	18200	2200	7200	12200 J	6300
Nickel	23000000	1600000	53100	210000	51700	62400 J	68900
Potassium			537000 J	361000 J	623000 J	284000 J	927000 J
Selenium	5700000	390000					
Silver	5700000	390000	2700	1200 J	2500	4300 J	4200
Sodium			457000 J	290000 J	666000 J	615000 J	944000
Thallium	79000	5000					
Vanadium	1100000	78000	22200	17900	22000	17100 J	37800
Zinc	110000000	23000000	934000	266000	551000	560000 J	864000

5/16/2008

Table 3-7
Landfill Features of Interest Sampling
Detected Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Landfill Feature		(A)	(B)	Feature 2	Feature 7	Feature 13	Feature 14	Feature 15	Feature 15
Sample ID		2008	2008	LTR-F02-2	LTR-F07-2	LTR-F13-2	LTR-F14-2	LTR-F15-2	LTR-F15-2DL
Lab Sample Number		NJ	NJ	Z2491-02	Z2491-05	Z2491-01	Z2491-04	Z2491-03	Z2491-03DL
Sampling Date		Nonresidential	Residential	4/21/2008	4/21/2008	4/21/2008	4/21/2008	4/21/2008	4/21/2008
Matrix		Soil Cleanup	Soil Cleanup	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
Dilution Factor		Criteria	Criteria	1	1	1	1	100	2000
Units		ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
Compound	CAS #								
Benzene	71-43-2	5,000	2,000					220000	(A,B)
Bromomethane	74-83-9	59,000	25,000			2000			
Chloromethane	74-87-3	12,000	4,000	6100		2300			
Cyclohexane	110-82-7						1800 J	1000000	
Dichloroethane-1,1	75-34-3	24,000	8,000					700000	(A,B)
Ethyl Benzene	100-41-4	110,000,000	7,800,000		1200 J	470 J	13000	65000 J	
Methylcyclohexane	108-87-2						4600	1400000	
Toluene	108-88-3	91,000,000	6,300,000					8400000	E (A,B)
Trichloroethane-1,1,1	71-55-6	4,200,000	290,000					660000	(A,B)
Xylene-o (1)	95-47-6	170,000,000	12,000,000		820 J	840 J	7700	99000 J	
Xylenes-m/p (1)	126777-61-2	170,000,000	12,000,000		3200	2100	22000	230000	
Total Confident Conc.				6100	5220	7710	49100	12774000	16000000
Total TICs									

Blank cell - compound not detected above MDL.

Qualifiers

U - The compound was not detected at the indicated concentration.

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater. The concentration given is an approximate value.

E (Organics) - Indicates the analyte 's concentration exceeds the calibrated range of the instrument for that specific analysis.

D - The reported value is from a secondary analysis with a dilution factor. The original analysis exceeded the calibration range.

(1) Criteria is for total xylenes

Table 3-8
Landfill Features of Interest Sampling
Detected Semi Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Landfill Feature		(A)	(B)	Feature 2	Feature 7	Feature 13	Feature 14	Feature 15
Sample ID		2008	2008	LTR-F02-2	LTR-F07-2	LTR-F13-2	LTR-F14-2	LTR-F15-2
Lab Sample Number		NJ	NJ	Z2491-02	Z2491-05	Z2491-01	Z2491-04	Z2491-03
Sampling Date		Nonresidential	Residential	4/21/2008	4/21/2008	4/21/2008	4/21/2008	4/21/2008
Matrix		Soil Cleanup	Soil Cleanup	SOIL	SOIL	SOIL	SOIL	SOIL
Dilution Factor		Criteria	Criteria	1	1	1	1	10
Units		ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg	ug/kg
Compound	CAS #							
Benzaldehyde	100-52-7	68,000,000	6,100,000					7300 J
Cresol-p	106-44-5	340,000	31,000			95 J		16000 J
Cresol-o	95-48-7	3,400,000	310,000					21000 J
Methylnaphthalene-2	91-57-6	2,400,000	230,000					4000 J
Naphthalene	91-20-3	17,000	6,000					16000 J ((A)
Phenanthrene	85-01-8	300,000,000					88 J	4700 J
Phenol	108-95-2	18,000,000				96 J		16000 J
Phthalate, bis(2-ethylhexyl)								
(DEHP)	117-81-7	140,000	35,000				150 J	16000 J
Pyrene	129-00-0	18,000,000	1,700,000				85 J	
Total Confident Conc.				0	0	191	323	101000
Total TICs								

Blank cell - compound not detected above MDL.

Qualifiers

U - The compound was not detected at the indicated concentration.

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater. The concentration given is an approximate value.

Table3-9
Lansdill Features of Interest Sampling
Metals
Diamond Head
Focused Phase 2 RI

Landfill Feature	2008	2008	Feature 2	Feature 7	Feature 13	Feature 14	Feature 14	Feature 15	Feature 15
Sample ID	NJ	NJ	LTR-F02-2	LTR-F07-2	LTR-F13-2	LTR-F14-2	LTR-F14-2	LTR-F15-2	LTR-F15-2
Lab Sample Number	Nonresidential	Residential	Z2491-02	Z2491-05	Z2491-01	Z2491-04	Z2491-04	Z2491-03	Z2491-03
Sampling Date	Soil Cleanup	Soil Cleanup	4/21/2008	4/21/2008	4/21/2008	4/21/2008	4/21/2008	4/21/2008	4/21/2008
Matrix	Criteria	Criteria	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
Dilution Factor			1	1	1	1	2	1	5
Units	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Compound	CAS #								
Aluminum	7429-90-5		78,000	23.5	1530	119	13000	13000	1190
Antimony	7440-36-0	450	31				6.04	6.04	1.63 J
Arsenic	7440-38-2	19	19		3.73	0.797 J	24.2 (A,B)	24.2 (A,B)	10.9
Barium	7440-39-3	59,000	16,000		88.7	5.72	419	419	50.3
Cadmium	7440-43-9	78	78	0.237 J	1.44 J	0.433 J	14.7	14.7	1.78
Calcium	7440-70-2			457	2170	379	9020	9020	551
Chromium	7440-47-3			1.03	20.6	4.2	146	146	32.5
Cobalt	7440-48-4	590	1,600		3.54	0.643 J	12.8	12.8	2.13
Copper	7440-50-8	45,000	3,100	3.46	125	6.2	383	383	55.9
Iron	7439-89-6			272	4870	4040	47300	47300	18500
Lead	7439-92-1	800	400	3.34	155	7.72	856 (A,B)	856 (A,B)	212
Magnesium	7439-95-4			387	1030	235	4020	4020	876
Manganese	7439-96-5	5,900	11,000	2.37	56.6	16.6	382	382	50.7
Mercury	7439-97-6	65	23		0.542		1.8	1.8	1.5
Nickel	7440-02-0	23,000	1,600	0.894 J	19	5.02	128	128	49.5
Potassium	9/7/7440			896	755	478	1370	1370	63.5 J
Silver	7440-22-4	5,700	390	0.32 J		0.251 J	1.05	1.05	0.741
Sodium	7440-23-5			12200	16000	29200	12300	12300	1020
Vanadium	7440-62-2	1,100	78		5.41	0.521 J	37.7	37.7	5.12
Zinc	7440-66-6	110,000	23,000	10.5	219	29.9	1340	1340	839
Cyanide		23,000	1,600		31				1.02
Total Confident Conc.				NA		NA	NA		NA
Total TICs									

Blank cell - compound not detected above MDL.

Table3-9
Lansdill Features of Interest Sampling
Metals
Diamond Head
Focused Phase 2 RI

Qualifiers

- U - The compound was not detected at the indicated concentration.
- J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater. The concentration given is an approximate
- B - The analyte was found in the laboratory blank as well as the sample. This indicates possible laboratory contamination of the environmental sample.
- P - For dual column analysis, the percent difference between the quantitated concentrations on the two columns is greater than 40%.
- * - For dual column analysis, the lowest quantitated concentration is being reported due to coeluting interference.
- E (Organics) - Indicates the analyte 's concentration exceeds the calibrated range of the instrument for that specific analysis.
- E (Inorganics) - The reported value is estimated because of the presence of interference.
- D - The reported value is from a secondary analysis with a dilution factor. The original analysis exceeded the calibration range.
- * - For dual column analysis, the lowest quantitated concentration is being reported due to coeluting interference.

Table 4-1
LNAPL Evaluation Sampling Program Summary
Diamond Head
Focused Phase 2 RI

Sample Type	Sample Description / Purpose	Sample Locations
Synthetic Precipitation Leaching Procedure (SPLP)	Soil sample using alternative laboratory leaching procedure simulating precipitation leaching over LNAPL for evaluation of potential leachate from residual LNAPL	MW-13D MW-14S PZ-2 PZ-10
LNAPL Sample Correlation with LIF	LIF probe exposed to site-specific free-phase LNAPL samples to determine laser response to the LNAPL	PZ-7 PZ-10 MW-13S
LIF Baseline Logs	Initial LIF borings installed at areas of "known conditions" to determine response of the LIF probe to site specific conditions	SB-27 - "clean" SB-29 - "clean" PZ-7 : 5.34' LNAPL in well 1/29/08 PZ-10 : 4.84' LNAPL in well 1/29/08 MW-13S : 4.68' LNAPL in well 1/29/08
LIF - Soil Core Correlation Logs	Conventional soil coring adjacent to LIF borings to observe and correlate LIF response with conventional soil core screening observations	LIF-017 - "Low" response @ 16.5%RE LIF-034 - "Medium" response @ 99.3%RE LIF-012 - "High" response @ 238.2%RE
Intact Soil Core Samples	Collection of intact soil cores in acetate core barrel liners that were flash-frozen and shipped to PTS Laboratories for specialized petrochemical analysis of LNAPL and soil characteristics	LIF-005 LIF-032 LIF-040 LIF-CAL-PZ-7
LNAPL Groundwater Pair Samples	LNAPL + Groundwater sample pairs collected from the LNAPL / Groundwater interface in monitoring wells for specialized petrochemical analysis of LNAPL characteristics by PTS Laboratories	PZ-7 MW-13S

Notes:

LNAPL = Light Non-Aqueous Phase Liquid

LIF = Laser Induced Fluorescence technology

SPLP = Synthetic Precipitation Leaching Procedure

Additional characterization samples were also collected for the Landfill Evaluation program

Table 4-2
Subsurface Soil
SPLP Sampling
Detected Volatile and Semi Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Soil boring location	SB-39	SB-40	SB-41	SB-42
Depth (ft)	6-May	8-Jul	15-17	6-May
Sample ID	SB-39-05-06-2	SB-40-07-08-2	SB-41-15-17-2	SB-42-05-06-2
Lab Sample Number	Z2074-01	Z2074-02	Z2074-03	Z2074-04
Sampling Date	3/17/2008	3/17/2008	3/17/2008	3/17/2008
Matrix	SPLP	SPLP	SPLP	SPLP
Dilution Factor	5	5	5	5
Units	ug/L	ug/L	ug/L	ug/L
Compound	CAS #			
Benzene	71-43-2	12 J		

Soil boring location	SB-39	SB-39	SB-40	SB-41	SB-41	SB-42
Depth (ft)	6-May	6-May	8-Jul	15-17	15-17	6-May
Sample ID	SB-39-05-06-2	SB-39-05-06-2DL	SB-40-07-08-2	SB-41-15-17-2	SB-41-15-17-2RE	SB-42-05-06-2
Lab Sample Number	Z2074-01	Z2074-01DL	Z2074-02	Z2074-03	Z2074-03RE	Z2074-04
Sampling Date	3/17/2008	3/17/2008	3/17/2008	3/17/2008	3/17/2008	3/17/2008
Matrix	SPLP	SPLP	SPLP	SPLP	SPLP	SPLP
Dilution Factor	1	5	1	1	1	1
Units	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L
Compound	CAS #					
Cresol-o	95-48-7	26	23 JD			16
Cresol-p	106-44-5	100 E	89 D			16

Blank cell - compound not detected above MDL.

Qualifiers:

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater. The concentration given is an approximate value.

E (Organics) - Indicates the analyte's concentration exceeds the calibrated range of the instrument for that specific analysis.

D - The reported value is from a secondary analysis with a dilution factor. The original analysis exceeded the calibration range.

Note: NJAC 7:9C Appendix Table 1 specified the NJ Class IIA groundwater quality criteria for benzene at 1 ug/L. The remaining compounds that were detected do not have established groundwater quality standards. Note that for the following VOCs, the detection limit exceeded the NJ Class IIA criteria for the compound: 1,1-DCE, Benzene (in the samples where it is shown as not detected), TCE and PCE.

Table 4-3
Phase 1 Subsurface Soil Detected Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Corresponding Phase 2 SPLP Sample:	SB-39		SB-40		SB-41		SB-42
Location QC Type Sample Depth	MW-13D 5-6 ft	MW-13D Duplicate 5-6 ft	MW-14S 7-8 ft	MW-14S Duplicate 7-8 ft	PZ-2 15-17 ft	PZ-2 Duplicate 15-17 ft	PZ-10 5-6 ft
Acetone		8500J	4100	7600	390J		
Benzene	2300J	1800J	420J	1300J		8800J	5700J
Bromomethane						470J	
Carbondisulfide		240J			10J	860J	
Carbontetrachloride							
Chlorobenzene	220J	160J		160J		700J	
Chloroform							1500J
Cyclohexane	8300J	6300J	1300J	3700		18000J	9200
Dichlorobenzene-1,2	30000J	21000J	1900	5200		20000J	26000
Dichlorobenzene-1,3		2100J				570J	2100J
Dichlorobenzene-1,4	3500J	2500J	280J			3600J	3500
Dichloromethane			230J	560			
Dichloroethane-1,1	410J	280J					
Dichloroethene-1,1							
Dichloroethene-1,2 cis	380J	520	180J	490J			
Dichloropropane-1,2						4600J	7600
Ethylbenzene	25000J	19000J	5200	15000			
Freon113					5J	46000J	44000
Hexanone	9500J						
Isopropylbenzene	7700J	6200J	1200J	3400			
Methylacetate	660J	11000J	330J		3J	12000J	11000
Methyl cyclohexane	11000J	7700J	3600	10000			
Methyl ethyl ketone (2-butanone)	23000J	33000J	25000	44000		55000J	26000
Methyl isobutyl ketone					100	560J	
Tetrachloroethane-1,1,2,2							3800
Tetrachloroethene (PCE)			1000J	2800J		1200J	
Toluene	26000J	20000J			6J	61000J	4800
Trichlorobenzene-1,2,4							70000
Trichloroethane-1,1,1							
Trichloroethene	520J	370J	2600	8500		770J	4400
Xylenes	160000DJ	140000DJ	34000	98000	7J	220000J	270000

All concentrations in ug/kg

Table 4-4
Phase 1 Subsurface Soil Detected Semi Volatile Organic Compounds
Diamond Head
Phase 2 Focused RI

Corresponding Phase 2 SPLP Sample:	SB-39		SB-40		SB-41		SB-42
Location QC Type Sample Depth	MW-13D 5-6 ft	MW-13D Duplicate 5-6 ft	MW-14S 7-8 ft	MW-14S Duplicate 7-8 ft	PZ-2 15-17 ft	PZ-2 Duplicate 15-17 ft	PZ-10 5-6 ft
Acenaphthene					1600J	9000	4100J
Acenaphthylene				6100J	5200	4600J	4100J
Anthracene				2100J	4000J	8500	8800J
Benzo(a)anthracene				6300J	14000J	18000	11000J
Benzo(a)pyrene				7600J	22000J	16000	7600J
Benzo(b)fluoranthene				6200J	17000J	9700	6900J
Benzo(ghi)perylene				5100J	15000J	11000	6500J
Benzo(k)fluoranthene				6000J	15000J	10000	5100J
Biphenyl-1,1			1300J		690J	2500J	3600J
Carbazole						390J	1300J
Chrysene				8300J	21000J	22000	11000J
Cresol-o							
Cresol-p					470J	1900J	2300J
Dibenz(a,h)anthracene					6100J	4300J	2300J
Dibenzofuran						1500J	5500J
Dimethyphenol-2,4							22000J
Fluoranthene	2400J	1400J		6200J	9000	26000	9200J
Fluorene					930J	4500J	5600J
Indeno(1,2,3-cd)pyrene				4300J	14000J	9200	77000J
2-Methylnaphthalene	39000J	20000J	5800J		2900J	74000	52000J
Naphthalene	24000J	12000J	2300J		4000J		
Nitrobenzene		4500J					
Phenanthrene		2800J	1300J	2700J	5500	17000	38000J
Phenol							
Phthalate, bis(2-ethylhexyl)							22000J
Phthalate, di-n-butyl						730J	
Pyrene		2200J		11000J	33000J	47000	30000J

All concentrations in ug/kg

Table 4-5
Consolidated Data Pertaining to LNAPL Characterization
Diamond Head
Focused Phase 2 RI

Phase 2 SPLP Sample	Phase 1 Soil Boring Correlation	Nearest LIF Boring	SPLP & Ph. 1 Sample Depth (feet bgs)	SPLP Detected Compounds (See Table 4-2)	Ph. 1 Soil Sample Total VOCs (ppb)	Ph. 1 Soil Sample Total SVOCs (ppb)	LIF %RE at Corresponding Depth Interval: Average & Maximum	LIF "Fingerprint" Color Code at Corresponding Depth	"Apparent" LNAPL Thickness in Well/Piez. 4/14/08 (feet)	Nearest LNAPL Pore Velocity (Mobility) Calculation	LNAPL Evaluation at this Location & Depth
SB-39	MW-13D	LIF-CAL-MW13S	5'-6'	Benzene: 12 ug/l Cresol-o: 26 ug/l Cresol-p: 100 ug/l	308,577 270,770 - dup	65,400 42,900 - dup	46 Max. 20 Avg.	Green	4.6' (MW-13S) Screened: 2-14' bgs	7.89×10^{-8} cm/s (0.1 ft/yr) [LIF-32]	Immobile, Potential Leaching Source
SB-40	MW-14S	LIF-003	7'-8'	None	81,340 200,710 - dup	10,700 71,900 - dup	33 Max. 28 Avg.	Green/Yellow	0' Screened: 2-16' bgs	3.7×10^{-9} cm/s (0.004 ft/yr) [LIF-005]	Immobile, Non-Source
SB-41	PZ-2	LIF-001	15'-17'	None	521 454,130 - dup	191390 297,820 - dup	na	na	0.28' Screened: 1-15' bgs	3.7×10^{-9} cm/s (0.004 ft/yr) [LIF-005]	Immobile, Non-Source
SB-42	PZ-10	LIF-CAL-PZ10	5'-6'	Cresol-o: 16 ug/l Cresol-p: 16 ug/l	489600	335900	29 Max. 22 Avg.	Green/Yellow	6.0' Screened: 1-16' bgs	3.7×10^{-9} cm/s (0.004 ft/yr) [LIF-CAL-PZ-7]	Immobile, Non-Source

Notes:

ppb = parts per billion
dup = duplicate sample
SPLP = Synthetic Precipitate Leachate Process
LIF = Laser Induced Fluorescence technology
Ph.1 = Phase 1 Remedial Investigation
%RE = % Reference Emitter for LIF technology
na = not analyzed
LNAPL = Light Non-Aqueous Phase Liquid
cm/s = centimeters per second
ft/yr = feet per year
VOC = Volatile Organic Compound
SVOC = Semi-Volatile Organic Compound
Piez. = Piezometer well

LIF "Fingerprint" Color Code Spectrum

Green	Yellow	Red	Orange
Less Weathered			More Weathered

Table 5-1
Free Product Sampling
Detected Volatile and Semi Volatile Organic Compounds and PCBs
Diamond Head
Focused Phase 2 RI

Well location		PZ-10	PZ-10
Sample ID		FP-PZ-10-2	FP-PZ-10-2
Lab Sample Number		Z2141-01	Z2141-01
Sampling Date		3/26/2008	3/26/2008
Matrix		SOIL	SOIL
Units		ug/kg	ug/kg
Compound	CAS #		
Volatile Organic Compounds			
Dilution Factor		100	
Benzene	71-43-2	11000 J	
Cyclohexane	110-82-7	22000 J	
Ethyl Benzene	100-41-4	98000	
Isopropylbenzene	98-82-8	19000 J	
Methylcyclohexane	108-87-2	57000	
Toluene	108-88-3	60000	
Xylenes-m/p	126777-61-2	350000	
Xylene-o	95-47-6	190000	
Total Confident Conc.		807000	
Total TICs			
Semi Volatile Organic Compounds			
Dilution Factor		10	
Naphthalene	91-20-3	280000 J	
2-Methylnaphthalene	91-57-6	370000 J	
Phenanthrene	85-01-8	120000 J	
Total Confident Conc.		770000	
Total TICs			
PCBs			
Dilution Factor		1	5
Aroclor-1232	11141-16-5	24000 E	20000 D
Aroclor-1260	11096-82-5	13000 E	12000 D
Total Confident Conc.		37000	32000
Total TICs			

Blank cell - compound not detected above MDL.

Qualifiers:

J - Data indicates the presence of a compound that meets the identification criteria. The

E (Organics) - Indicates the analyte 's concentration exceeds the calibrated range of the instrument for that specific analysis.

D - The reported value is from a secondary analysis with a dilution factor. The original analysis exceeded the calibration range.

Table 5-2
Free Product Sampling
Detected Metals and Cyanide
Diamond Head
Focused Phase 2 RI

Well location		PZ-10
Sample ID		FP-PZ-10-2
Lab Sample Number		Z2141-01
Sampling Date		3/26/2008
Matrix		OTHER
Dilution Factor		1
Units		mg/Kg
Compound	CAS #	
Aluminum	7429-90-5	47.9
Arsenic	7440-38-2	1.89
Barium	7440-39-3	750
Calcium	7440-70-2	1540
Chromium	7440-47-3	61.5
Copper	7440-50-8	39.7
Iron	7439-89-6	422
Lead	7439-92-1	400
Magnesium	7439-95-4	75.1
Manganese	7439-96-5	20.2
Mercury	7439-97-6	0.12
Nickel	7440-02-0	2.08
Potassium	9/7/7440	6.13 J
Vanadium	7440-62-2	53.8
Zinc	7440-66-6	10.1
Total Confident Conc.		NA
Total TICs		
Units		ug/L
Cyanide	57-12-5	2.2 J

Blank cell - compound not detected above MDL.

Qualifiers:

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater. The concentration given is an approximate value.

Table 6-1
Summary of Soil and LNAPL Modeling Parameters - Laboratory Capillary Data Curve Fitting
Diamond Head
Focused Phase 2 RI

Soil Parameters Total Porosity (%) Van Genuchten "N" Van Genuchten Air-Water "alpha" (1/cm) Residual Water Saturation (frac Pv) Water Saturated Hydraulic Conductivity (cm/sec)	LIF-040-00-05-2	LIF-032-01-05-2	LIF-P27-09-13-2	LIF-005-08-15-2	Comments PTS Lab Data (Pore Fluid Saturation Test) from Curve Fit Summary sheet from Curve Fit Summary sheet from Curve Fit Summary sheet PTS Lab Data (Capillary Pressure Test)
	Medium Sand	Fine Sand	Silt	Fine Sand	
	0.8' bgs	2.2' bgs	10.6' bgs	10.2' bgs	
	49.9	24.1	74.7	78.6	
	1.597	1.479	1.625	1.314	
	0.0079	0.0364	0.0076	0.0046	
	0.248	0.383	0.599	0.316	
	2.47E-04	3.12E-04	5.38E-05	4.52E-05	
Groundwater and LNAPL Parameters (50°F) Groundwater Density (g/cc) LNAPL Density (g/cc) Water Viscosity (centipoise) LNAPL Viscosity (centipoise) Air-Water Surface Tension (dyne/cm) Air-LNAPL Surface Tension (dyne/cm) LNAPL-Water Surface Tension (dyne/cm) Air-LNAPL Scaling Factor LNAPL-Water Scaling Factor In Situ LNAPL Thickness (feet) LNAPL Gradient (ft/ft)					PTS Lab Data - PZ7 LNAPL Sample (scaled to 50°F) PTS Lab Data - PZ7 LNAPL Sample (scaled to 50°F) PTS Lab Data - PZ7 LNAPL Sample (scaled to 50°F) PTS Lab Data - PZ7 LNAPL Sample (scaled to 50°F) PTS Lab Data - PZ7 LNAPL Sample PTS Lab Data - PZ7 LNAPL Sample PTS Lab Data - PZ7 LNAPL Sample Calculated from Surface Tension Data Calculated from Surface Tension Data Static value at PZ-7 prior to LNAPL baildown test Assumed maximum value based on typical hydraulic gradients

Table 6-2
Comparison of Maximum LNAPL Saturations (%) From Different Curve-Fitting Analyses
Diamond Head
Focused Phase 2 RI

Location ID	<i>Field Measured</i>	<i>Raw Capillary Data</i>	<i>Refined Curve Fit</i>
LIF-040-00-05-2	50.1	17.1	51.0
LIF-032-01-05-2	36.6	33.4	44.4
LIF-PZ7-09-13-2	44.1	9.0	52.4
LIF-005-08-15-2	39.5	6.1	44.6

Table 6-3
Summary of Soil and LNAPL Modeling Parameters - Laboratory Pore Fluid Saturations Data Curve Fitting
Diamond Head
Focused Phase 2 RI

Summary of Soil and LNAPL Modeling Parameters - Laboratory Pore Fluid Saturations Data Curve Fitting

LNAPL Mobility Assessment

Diamond Head Oil Superfund Site

	LIF-040-00-05-2 Medium Sand	LIF-032-01-05-2 Fine Sand	LIF-PZ7-09-13-2 Silt	LIF-005-08-15-2 Fine Sand	Comments
Soil Parameters	0.8' bgs	2.2' bgs	10.8' bgs	10.2' bgs	
Total Porosity (%)	49.9	24.1	74.7	78.6	PTS Lab Data (Pore Fluid Saturation Test)
Van Genuchten "N"	1.620	1.722	2.518	1.623	Estimated from manual curve fit based on measured LNAPL saturations from PTS
Van Genuchten Air-Water "alpha" (1/cm)	0.0738	0.0722	0.0262	0.0320	Estimated from manual curve fit based on measured LNAPL saturations from PTS
Residual Water Saturation (frac Pv)	0.250	0.250	0.250	0.250	Assumed constant value for manual curve fitting
Water Saturated Hydraulic Conductivity (cm/sec)	2.47E-04	3.12E-04	5.38E-05	4.52E-05	PTS Lab Data (Capillary Pressure Test)
Groundwater and LNAPL Parameters (50°F)					
Groundwater Density (g/cc)			1.000		PTS Lab Data - PZ7 LNAPL Sample (scaled to 50°F)
LNAPL Density (g/cc)			0.903		PTS Lab Data - PZ7 LNAPL Sample (scaled to 50°F)
Water Viscosity (centipoise)			1.159		PTS Lab Data - PZ7 LNAPL Sample (scaled to 50°F)
LNAPL Viscosity (centipoise)			271.155		PTS Lab Data - PZ7 LNAPL Sample (scaled to 50°F)
Air-Water Surface Tension (dyne/cm)			44.4		PTS Lab Data - PZ7 LNAPL Sample
Air-LNAPL Surface Tension (dyne/cm)			33.2		PTS Lab Data - PZ7 LNAPL Sample
LNAPL-Water Surface Tension (dyne/cm)			6.8		PTS Lab Data - PZ7 LNAPL Sample
Air-LNAPL Scaling Factor			1.34		Calculated from Surface Tension Data
LNAPL-Water Scaling Factor			6.53		Calculated from Surface Tension Data
In Situ LNAPL Thickness (feet)	4.26	2.29	4.00	6.46	Estimated from manual curve fit
LNAPL Gradient (ft/ft)	0.010	0.010	0.010	0.010	Assumed maximum value based on typical hydraulic gradients

Table 6-4
Comparison of Maximum LNAPL Conductivity Values – Raw Capillary Data Versus Refined
Curve-fit Parameters
Diamond Head
Focused Phase 2 RI

Location ID	Maximum LNAPL Conductivity (cm/sec)		Median Grain Size (mm)
	Raw Capillary Data	Refined Parameters	
LIF-040-00-05-2	2.65×10^{-7}	7.54×10^{-7}	0.432
LIF-032-01-05-2	8.32×10^{-7}	8.29×10^{-7}	0.121
LIF-PZ7-09-13-2	5.49×10^{-8}	1.43×10^{-7}	0.031
LIF-005-08-15-2	3.04×10^{-8}	1.25×10^{-7}	0.085

Table 6-5
Free-product Mobility Tests – Initial and Residual Saturations (% P_v)
Diamond Head
Focused Phase 2 RI

Sample ID	Porosity (% V _b)	<i>Initial Fluid Saturations</i>		<i>After Centrifuge at 1,000 x Gravity</i>	
		Water Saturation	LNAPL Saturation	Water Saturation	LNAPL Saturation
LIF-040-00-05-2 (0.9 foot bgs)	46.8	81.4	4.7	48.6	4.7
LIF-032-01-05-2 (2.1 feet bgs)	35.6	66.5	5.4	42.2	5.4
LIF-PZ7-09-13-2 (10.7 feet bgs)	62.9	82.4	17.1	43.5	12.9
LIF-005-08-15-2 (10.45 feet bgs)	72.0	72.3	7.4	37.9	7.4

% P_v = percent pore volume
 % V_b = percent bulk volume

Table 6-6
Comparison of Maximum LNAPL Pore Velocity Values – Raw Capillary Data Versus Refined
Curve-Fitting Parameters
Diamond Head
Focused Phase 2 RI

Maximum LNAPL Pore Velocity

Location ID	Raw Capillary Data	Refined Parameters
	3.16 x 10 ⁻⁸ cm/sec	3.19 x 10 ⁻⁸ cm/sec
LIF-040-00-05-2	(8.96 x 10 ⁻⁵ ft/yr)	(9.04 x 10 ⁻⁵ ft/yr)
	1.15 x 10 ⁻⁷ cm/sec	7.89 x 10 ⁻⁸ cm/sec
LIF-032-01-05-2	(3.26 x 10 ⁻⁴ ft/yr)	(2.24 x 10 ⁻⁴ ft/yr)
	8.34 x 10 ⁻⁹ cm/sec	3.70 x 10 ⁻⁹ cm/sec
LIF-PZ7-09-13-2	(2.36 x 10 ⁻⁵ ft/yr)	(1.05 x 10 ⁻⁵ ft/yr)
	7.90 x 10 ⁻⁹ cm/sec	3.70 x 10 ⁻⁹ cm/sec
LIF-005-08-15-2	(2.24 x 10 ⁻⁵ ft/yr)	(1.05 x 10 ⁻⁵ ft/yr)

Table 6-7
Recovery Model Parameters – Fluid Parameters
Diamond Head
Focused Phase 2 RI

Parameter	Value
Density (g/cm ³)	0.9027
Viscosity (centipoise)	271.155
Interfacial Tension – Air/Water (dynes/cm)	44.40
Interfacial Tension – Air/LNAPL (dynes/cm)	33.20
Interfacial Tension – LNAPL/Water (dynes/cm)	6.80
Residual Water Saturation (% Pore volume)	0.25
Residual LNAPL Saturation (% Pore volume) ¹	0.00

1. A residual LNAPL saturation of zero was used to conservatively simulate that all LNAPL in the subsurface was recoverable.

Table 6-8
Recovery Model Parameters – Specific Soil/Location Parameters
Diamond Head
Focused Phase 2 RI

Parameter	LIF-040	LIF-032	PZ-7	LIF-005
LNAPL Thickness (feet)	4.26	2.29	4.00	6.46
Porosity (-)	0.499	0.241	0.747	0.786
Saturated Hydraulic Conductivity (feet/day)	0.7002	0.8844	0.1525	0.1281
Van Genuchten alpha (feet ⁻¹)	2.249	2.200	0.7986	0.9754
Van Genuchten N (-)	1.620	1.722	2.518	1.623

Table 6-9
Results of LNAPL Recovery Model After 30 Years of Operation
Diamond Head
Focused Phase 2 RI

Location ID	Total Recovery Volume (gallons)	Percent Recovery (%)
LIF-040-00-05-2	123	5.4
LIF-032-01-05-2	33	6.6
LIF-PZ7-09-13-2	16	0.52
LIF-005-08-15-2	45	0.94

Table 7-1
Air/Bio Sparge Pilot Test Groundwater Sampling
Detected Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Station ID	MW-11S	MW-11S	PZ-AS-01	PZ-AS-01	PZ-AS-02	PZ-AS-02	PZ-AS-03
Sample ID	MW-11S-1-2	MW-11S-2-2	PZ-AS-01-1-2	PZ-AS-01-2-2	PZ-AS-02-1-2	PZ-AS-02-2-2	PZ-AS-03-1-2
Sample Date	04/07/2008	04/18/2008	04/08/2008	04/18/2008	04/08/2008	04/18/2008	04/08/2008
Chemical Name							
Volatile Organic Compounds (ug/l)							
Acetone			75	170	47 J	89	130
Benzene			12	8.5	3.9 J	11	11
Chlorobenzene			7.6	4.7 J			
Cyclohexane			3 J			0.51 J	0.86 J
Dichlorobenzene-1,4							
Dichloroethane-1,1			2 J		1.1 J	3.1 J	1.7 J
Dichloroethene-1,2 trans							0.48 J
Dichloroethylene-1,2 cis	1.7 J	2.2 J	72	43	36	84	64
Dioxane, 1,4-							24 J
Ethylbenzene			22	14		14	16
Isopropylbenzene			2.6 J	1.3 J	0.35 J	0.94 J	1.6 J
Methyl acetate							
Methyl cyclohexane			6.3				
Methyl ethyl ketone (2-butanone)			13	41	8.9 J	20	20
Methyl isobutyl ketone (4-methyl-2-pentanone)			9.5 J	22	3.2 J	7.6 J	12
Tetrachloroethylene			12	9.5	13	31	13
Toluene			54	40	12	35	52
Trichloroethylene			4 J	2.9 J	2.2 J	5.4	3.7 J
Xylene-o			58	42	15	41	47
XYLENES, M & P			84	61	19	57	63

6/18/2008

Table 7-1
Air/Bio Sparge Pilot Test Groundwater Sampling
Detected Volatile Organic Compounds
Diamond Head
Focused Phase 2 RI

Station ID	PZ-AS-03	PZ-AS-04	PZ-AS-04	PZ-AS-05	PZ-AS-05
Sample ID	PZ-AS-03-2-2	PZ-AS-04-1-2	PZ-AS-04-2-2	PZ-AS-05-1-2	PZ-AS-05-2-2
Sample Date	04/18/2008	04/08/2008	04/18/2008	04/07/2008	04/18/2008
Chemical Name					
Volatile Organic Compounds (ug/l)					
Acetone	230		60	130	240
Benzene	19		4.4 J	2.9J	5.3
Chlorobenzene					
Cyclohexane				1.9J	
Dichlorobenzene-1,4				0.75J	0.92 J
Dichloroethane-1,1	2.1 J				
Dichloroethene-1,2 trans					
Dichloroethylene-1,2 cis	65	1 J	46	4.1J	11
Dioxane, 1,4-					
Ethylbenzene	23		5.3	13	16
Isopropylbenzene	2.3 J		0.69 J	1.7J	2.1 J
Methyl acetate				6.9	5.2
Methyl cyclohexane					
Methyl ethyl ketone (2-butanone)	55		13	7J	36
Methyl isobutyl ketone (4-methyl-2-pentanone)	54		5.2 J	2.8J	14
Tetrachloroethylene	13	1.2 J	8.3	8.7	11
Toluene	83	1.4 J	14	18	27
Trichloroethylene	6.5		1.5 J	1.1J	1.7 J
Xylene-o	66	1.6 J	14	34	45
XYLENES, M & P	90	2.6 J	25	51	67

6/18/2008

Table 7-2
Air/Bio Sparge Pilot Test
Phospholipid Fatty Acid (PLFA) Results Summary
Diamond Head
Focused Phase 2 RI

Sample Identification:	Total Biomass (cells/mL)	Firmicutes (TerBrSats)	Proteobacteria (Monos)	Anaerobic Metal Reducers (BrMonos)	SRB/ Actinomycetes (MidBrSats)	General (Nsats)	Eukaryotes (polyenoics)	Slowed Growth	Decreased Permeability
Unit:	cells/mL	%	%	%	%	%	%	ratio cy/cis	ratio trans/cis
PZ-AS-01-1-2 (Baseline)	1.36E+05	10.56	66.17	1.49	2.44	16.27	3.07	0.696299683	0.153922553
PZ-AS-01-2-2 (Post A/B Sparge)	2.91E+05	7.05	71.94	2.50	2.57	13.25	2.69	0.087454862	0.022199798
% change:	113.97	-33.24	8.72	67.79	5.33	-18.56	-12.38	-87.44	-85.58
PZ-AS-02-1-2 (Baseline)	3.95E+04	19.26	39.97	1.62	1.27	30.67	7.23	1.193183669	0.126153846
PZ-AS-02-2-2 (Post A/B Sparge)	1.59E+04	14.13	49.95	1.82	2.58	29.39	2.14	0.259523079	0.000000000
% change:	-59.75	-26.64	24.97	12.35	103.15	-4.17	-70.40	-78.25	-100.00
PZ-AS-03-1-2 (Baseline)	3.52E+04	11.92	53.45	2.28	2.26	22.26	7.84	0.561150834	0.165372680
PZ-AS-03-2-2 (Post A/B)	9.20E+04	4.27	77.94	0.00	0.65	13.74	3.42	0.172235268	0.167380631
% change:	161.36	-64.18	45.82	-100.00	-71.24	-38.27	-56.38	-69.31	1.21
PZ-AS-04-1-2 (Baseline)	8.49E+05	9.97	58.91	2.42	3.54	19.45	5.71	0.504731345	0.108495445
PZ-AS-04-2-2 (Post A/B Sparge)	1.01E+06	9.17	70.09	1.15	1.90	14.49	3.21	0.079938078	0.051266766
% change:	18.96	-8.02	18.98	-52.48	-46.33	-25.50	-43.78	-84.16	-52.75
PZ-AS-05-1-2 (Baseline)	6.53E+05	6.44	71.60	1.79	1.45	13.79	4.94	0.163073932	0.025357143
PZ-AS-05-2-2 (Post A/B Sparge)	9.30E+05	1.51	81.07	0.62	0.53	14.50	1.78	0.035804336	0.025715111
% change:	42.42	-76.55	13.23	-65.36	-63.45	5.15	-63.97	-78.04	1.41
MW-11S-1-2 (Baseline)	2.33E+06	6.50	67.80	1.68	2.28	14.04	7.71	0.187747742	0.086730932
MW-11S-2-2 (Post A/B Sparge)	2.62E+05	5.48	69.94	1.68	2.21	14.79	5.91	0.221355797	0.055273698
% change:	-88.76	-15.69	3.16	0.00	-3.07	5.34	-23.35	17.90	-36.27

Notes:

BrMonos: Branched Monoenoic

Cis: Cis fatty acid

Cy: Cyclopropyl

MidBrSats: Mid-Chain Branched Saturated

mL: milliliter

Monos: Monoenoic

NSats: Normal Saturated

TerBrSats: Terminally Branched Saturated

Trans: Trans fatty acid

* Negative % change values denote reductions.

Table 8-1
Landfill Features of Interest Sampling
IDW Characterization
Diamond Head
Focused Phase 2 RI

Landfill Feature		Feature 2	Feature 15	Feature 15	TCLP limit
Sample ID		LTR-F02-2	LTR-F15-2	LTR-F15-2DL	
Lab Sample Number		Z2491-06	Z2491-07	Z2491-07DL	
Sampling Date		4/21/2008	4/21/2008	4/21/2008	
Matrix		TCLP	TCLP	TCLP	
Units		ug/l	ug/l	ug/l	ug/l
Compound	CAS #				
Organic Compounds					
Dilution Factor		5	5	20	
Benzene	71-43-2		1100 E	650 D	500
Dichloroethane-1,2	107-06-2		2		500
Methyl ethyl ketone (2-butanone)	78-93-3		320	440 JD	200000
Total Confident Conc.		0	1422	1090	
Total TICs					
Metals					
Dilution Factor		1	1		
Barium	7440-39-3		1280		100000
Cadmium	7440-43-9	10.4 J	24.8 J		1000
Chromium	7440-47-3	35.9 J	88.4		5000
Lead	7439-92-1	86.4 J	575		5000
Hazardous waste characteristics					
Corrosivity (as pH)		9	5.4		
Ignitability		No	No		

Blank cell - compound not detected above MDL.

Qualifiers:

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater. The concentration given is an approximate value.

E (Organics) - Indicates the analyte 's concentration exceeds the calibrated range of the instrument for that specific analysis.

D - The reported value is from a secondary analysis with a dilution factor. The original analysis exceeded the calibration range.

Table 8-2
Free Product Sampling
IDW Characterization
Diamond Head
Focused Phase 2 RI

Water material		Free product	TCLP limit
Sample ID		FP-IDW-01-2	
Lab Sample Number		Z2141-02	
Sampling Date		3/26/2008	
Matrix		TCLP	
Units		ug/l	ug/l
Compound	CAS #		
Volatile Organic Compounds			
Dilution Factor		5	
None detected			
Semivolatile Organic Compounds			
Dilution Factor		1	
None detected			
Pesticides			
Dilution Factor		10	
None detected			
Herbicides			
Dilution Factor		1	
None detected			
Metals			
Dilution Factor		1	
Barium	7440-39-3	484 J	100000
Chromium	7440-47-3	42.1 J	5000
Lead	7439-92-1	348	5000
Selenium	7782-49-2	59.9 J	1000
Silver	7440-22-4	7.5 J	5000

Blank cell - compound not detected above MDL.

Qualifiers:

J - Data indicates the presence of a compound that meets the identification criteria. The result is less than the quantitation limit but greater. The concentration given is an approximate value.

Table 8-3
Free Product and Decon Water Sampling
IDW Characterization
Ignitability and Corrosivity
Diamond Head
Focused Phase 2 RI

Water material	Free product	Decon water
Sample ID	FP-IDW-01-2	WW-01-2
Lab Sample Number	Z2141-02	Z2141-03
Sampling Date	3/26/2008	3/26/2008
Matrix	WATER	WATER
Dilution Factor	1	1
Ignitability	0	0
Corrosivity (as pH)	5.9	7

Table 8-4
Decon Water Sampling
IDW Characterization
Diamond Head
Focused Phase 2 RI

Station ID	WW-01-2
Sample ID	WW-01-2
Sample Date	4/18/2008
Volatile Organic Compounds:	(ug/l)
Methyl isobutyl ketone	
(4-methyl-2-pentanone	1.4 J